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A World Review of
DESIGN & PRODUCTION · RESEARCH & DEVELOPMENT

VOL. XXII No. 2 FEBRUARY 1961

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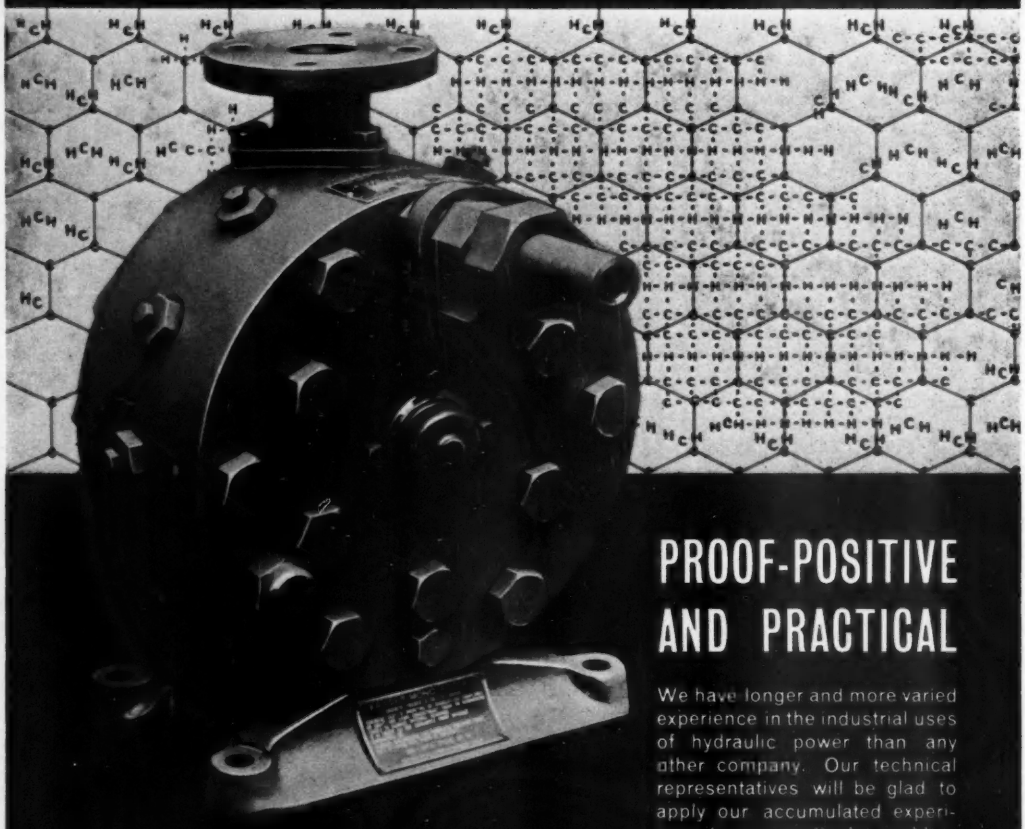

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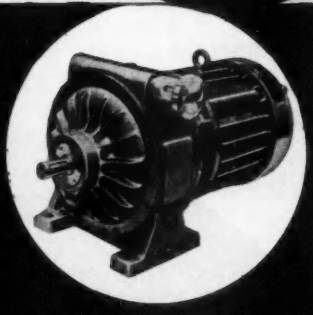

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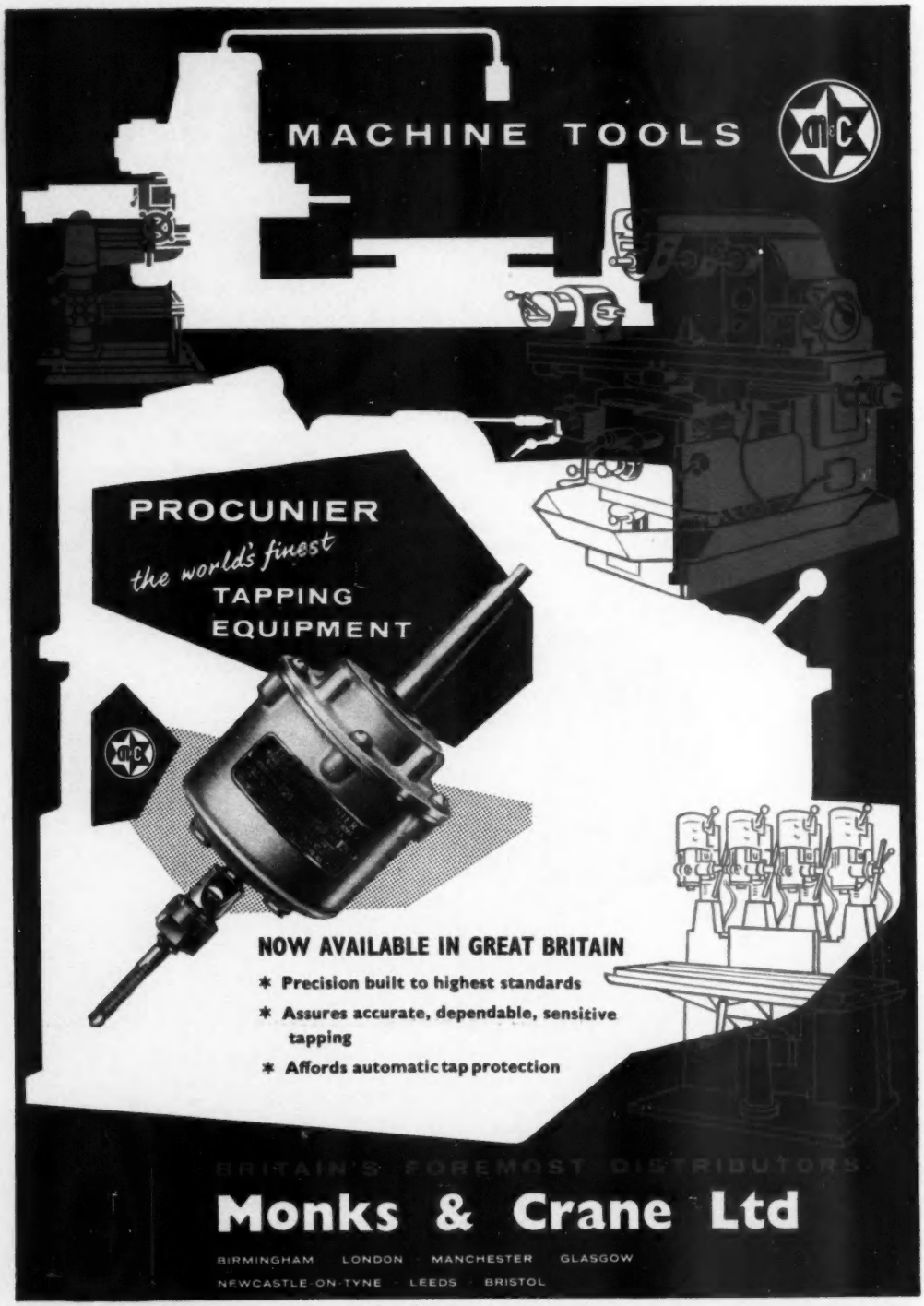
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The ENGINEERS' DIGEST

A World Review of DESIGN & PRODUCTION · RESEARCH & DEVELOPMENT

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A programme aimed at accumulating the necessary background information on refractory metals for the **development of a columbium-tungsten-tantalum alloy for high-temperature applications** (up to 3500°F) is being undertaken by the Union Carbide Corporation, in co-operation with the U.S. Air Force. The new programme will be carried out in three phases, the first of which will cover the effects of interstitial impurity elements on the mechanical properties of refractory metals as a class, while the second phase will be concerned with high-temperature strengthening, and the third phase will comprise a study of oxidation behaviour in the temperature range between 2000° and 3000°F. Particular attention will be directed to those columbium- and tantalum-base alloys which show maximum oxidation resistance.

* * *

According to an article in *Priborostroyeniye* for November 1960, it is claimed that the productivity of finishing operations has been increased by a factor of 3 as the result of the introduction of a new Russian **galvano-abrasive process for finishing instrument components,** such as the spindles of electrical counters. In this process, the components are placed in a rotating barrel, where they are first tumbled in a 10% solution of sodium phosphate with an abrasive powder and a number of copper balls of from 1 to 3 mm diameter, the copper balls forming with the steel components a galvanic couple with a potential difference of about 0·6 V. After tumbling, the components are then burnished in the barrel in a solution of slaked lime with abrasive powder and pieces of porcelain, after which they are polished by tumbling in a soap solution containing pieces of porcelain and are then finally dried in sawdust.

* * *

A new approach to the design of the storage target assembly has been embodied in an **improved bi-stable direct-viewing storage tube** recently developed by the English Electric Valve Co. Ltd., of Chelmsford, Essex. The use of this new technique involves far less risk of damage to the assembly in cases where a high beam current is accidentally applied and enables the associated circuitry to be simplified. The tube, which has a viewing-screen diameter of 4 in., utilizes an electrostatically deflected and focused writing gun which deposits a charge pattern on the storage mesh, the spot diameter being about

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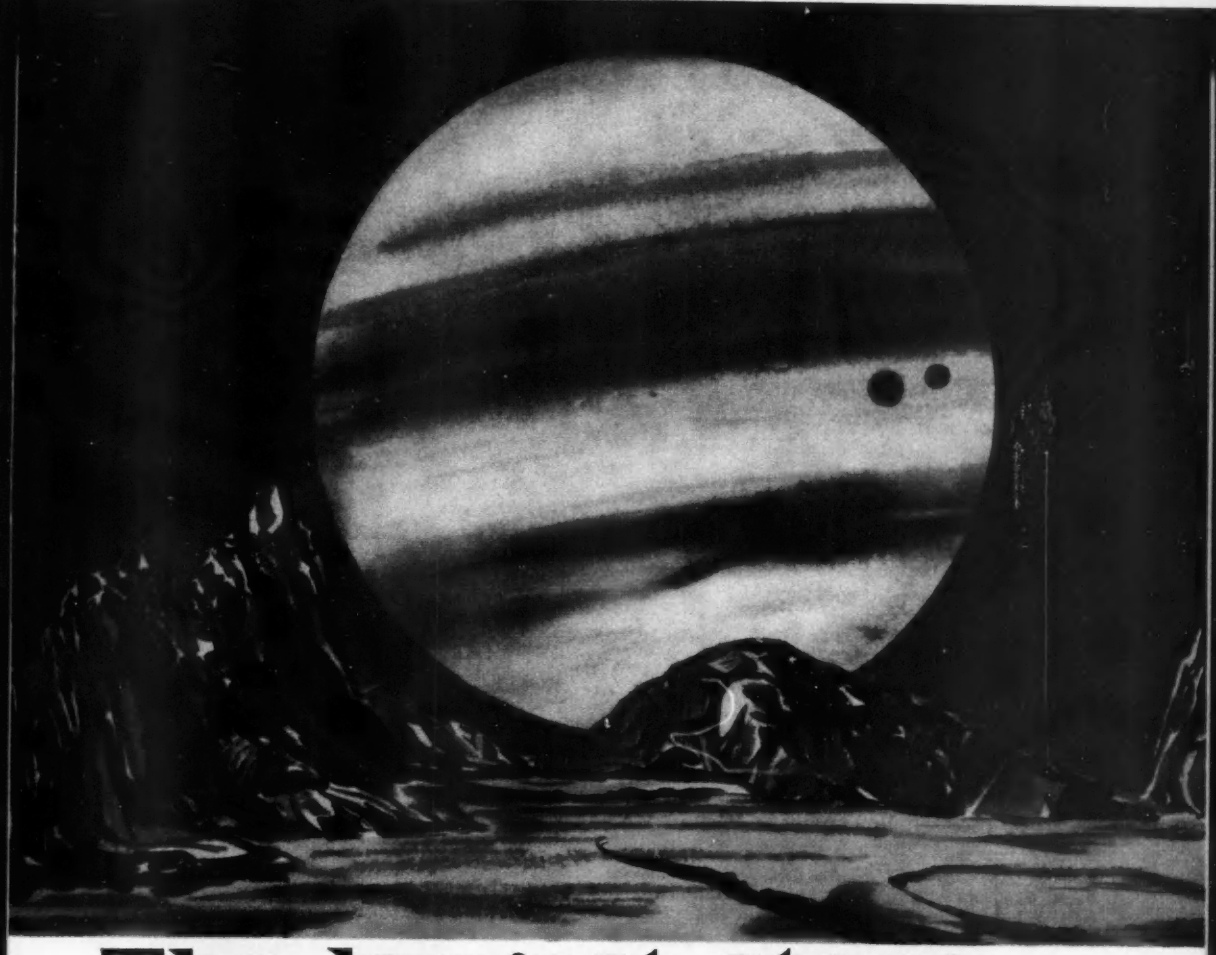

The largest stone in the Universe

This is the mighty planet Jupiter swinging majestically round the Sun at a distance five times that of the Earth. The artist has set you down on Europa, one of its retinue of satellites, and you look out over the eerie, alien, scenery towards the giant belted globe of Jupiter 415,000 miles distant, glowering against an almost black canopy of eternal night.

According to modern atomic theory, at extremely high pressure atoms can become crushed and matter can collapse in upon itself. Even the entire Earth is far too light to achieve this pressure but at the centre of Jupiter, which is 317 times heavier than the Earth, this pressure is almost reached. If Jupiter was any bigger the matter at its centre would literally buckle and the planet would contract. For this reason when you see Jupiter you can fairly claim to be looking at the 'largest stone in the Universe.'

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The MINIDIGEST

0·010 in., while a second gun, which floods the storage mesh continuously, maintains this signal and displays it on the phosphor. The tube can store information indefinitely and permits continuous or intermittent display of the stored waveform. Two or more signals can be stored and displayed at the same time, and instantly erased when no longer required.

* * *

Details are given in a paper in the *Review of the Electrical Communication Laboratory* (May-June, 1960) of the Nippon Telegraph and Telephone Public Corporation, of the development in Japan of a new **cotton-flock and flax paper for laminates,** with large crystalline regions and a high degree of polymerization in the cellulose. It has been found that, when cotton flock is cooked in a solution of NaOH, the relation between the percentage amount x of NaOH and the relative viscosity or amount y of α-cellolose can be expressed as $y = ae^{bx}$, where a and b are constants. It has also been found that maturing of the cooked pulps has the beneficial effect of increasing the absorptivity of the paper. Coloured papers, as well as papers with wear-resistant fillers, have also been developed. It is stated that all these papers have a high tensile strength and, when used for laminates, show good dimensional stability and a high electrical resistance.

* * *

Developed by The M. W. Kellogg Company, of New York, a **new type of fuel cell** operates on a mercury amalgam of sodium, oxygen, and water, and is stated to produce twice the voltage of hydrogen cells. In this connection, the new cell offers the advantage of sharply decreased plant volume, as fewer cells are required for a power-plant of appreciable size, and storage requirements for sodium are considerably less than they are for hydrogen. In fact, it is claimed that the prototype will develop about 75 kW and, together with fuel storage space, will be about fifteen times lighter than equivalent standard electric batteries now in use, its weight being between 2 and 3 lb per kWhr of capacity.

* * *

Details of recent experiments carried out in connection with the **chemical machining of aluminium** are given in Issue No. 9-10, 1960, of the *Report of the Japan Government Industrial Research Institute*, at Nagoya. In these experi-

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The MINIDIGEST

ments, aluminium bars of square and of circular cross-section were taper-machined in an aqueous solution of sodium hydroxide or in hydrochloric acid, and the results indicated that the straightness of the tapered parts increased if chemical machining was carried out with repeated dipping, instead of with a single dip. It was also found that the quality of machining improved with increasing dipping speed, and that, on the whole, sodium hydroxide baths were preferable to those using hydrochloric acid. It was noted that, with increasing concentrations of the sodium hydroxide solution, tapering first increased sharply and then levelled off, whereas the degree of tapering appeared to increase with increasing temperature in accordance with a square law.

* * *

According to a report in *Prace Instytutów Hutniczych* for December 1960, successful tests have been carried out in Poland with regard to the **dry-galvanizing or aluminizing of low-carbon steel wire under a protective atmosphere of hydrogen.** It is claimed that, with this method, coatings of good mechanical and physical properties can be obtained, the major advantage, however, being that conventional acid pickling of the wire can be eliminated.

* * *

As reported in *Materials in Design Engineering* for December 1960, the fact that diallyl phthalate has excellent retention of its electrical properties under conditions of high humidity, as it absorbs virtually no moisture, has led to the development of this material in the form of a **conductive plastic to replace resistance wire in precision potentiometers.** In the construction of these potentiometers, the conductive compound, comprising diallyl phthalate and a carbon filler, is inserted into a recessed ring on the compression mould and is then covered with standard insulation-type diallyl phthalate, after which the element and base are moulded as one piece. It is stated that the use of this conductive material has the advantage of reducing the electrical noise normally caused by uneven surface resistance by allowing the wiper to ride on the smooth, low-friction surface of the plastic, with the additional advantages of reduced wiper wear and very low turning torque. Also, the conductive diallyl phthalate ring eliminates the jumps in resistance generally caused when a wiper passes from one wire coil to another.

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BUSINESS NOTES

Charles Churchill & Co. Ltd., of South Yardley, Birmingham, announce a further addition to the Group in the incorporation of **Denham's Engineering Co. Ltd.**, of Halifax. While the range of general-purpose lathes made by this company will be continued, the manufacturing capacity will be expanded to enable the production of other machines within the range handled by the **Charles Churchill Group** to be undertaken. Denham's Engineering Co. Ltd. will, like other companies in the Group, continue to function as an autonomous unit and will for the present maintain its own selling arrangements.

* * *

It is announced by **John Brown & Co. Ltd.** that their subsidiary company, **John Brown (S.E.N.D.) Ltd.**, have concluded an agreement with **DEMAG Aktiengesellschaft Duisberg** for the manufacture and supply in the U.K. of a wide range of iron- and steel-works plant to the designs of DEMAG, one of the largest and oldest manufacturers of this type of equipment in Europe. John Brown (S.E.N.D.) Ltd. is the organization in the **John Brown Group** which undertakes the designing and contracting for engineering products that are new to the John Brown subsidiary companies, and co-ordinates the manufacture of these new products amongst their appropriate works.

* * *

The **English Steel Corporation Ltd.**, of Sheffield, announce that the telephone number of their River Don Works, Grimesthorpe Works, Stevenson Road Works, Park Works, and Tinsley Park Works, has been changed to Sheffield 49071.

* * *

It is announced by **The Villiers Engineering Co. Ltd.**, of Wolverhampton, that they have purchased the firm of **John Roper & Son, Ltd.**, also of Wolverhampton, who have specialized in the production of straight and spiral bevel gears and of spur and helical gears.

* * *

In accordance with the terms of an agreement signed between **Simms Motor Units Ltd.**, of London, N.2, and the **Bendix Corporation**, of Detroit, Michigan, Simms have granted to Bendix an exclusive manufacturing licence and selling rights throughout the U.S.A. for their diesel fuel-injection equipment, including fuel-injection pumps, governors, injectors, filters, and couplings. At the same time, the Bendix Corporation have acquired non-exclusive selling rights for this equipment in Canada, Mexico, and Brazil, and will assume complete responsibility for servicing throughout the area. The Simms interests will be handled by the **Scintilla Division** of the Bendix Corporation, occupying a site of over 98 acres at Sidney, N.Y., with a floor area at present in use of over 600,000 sq ft.

* * *

G. H. Osborn Building Products Ltd., of Isleworth, Middlesex, announce that they have set up a new division within the company for the manufacture of industrial reinforced-plastics products. The new division, though

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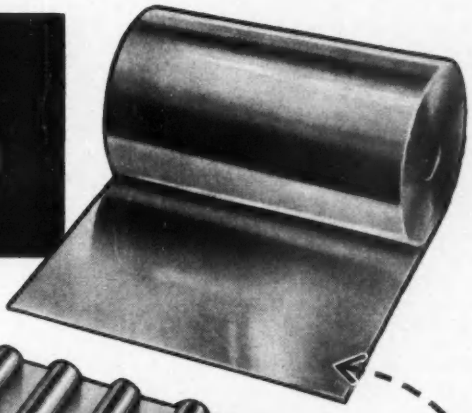

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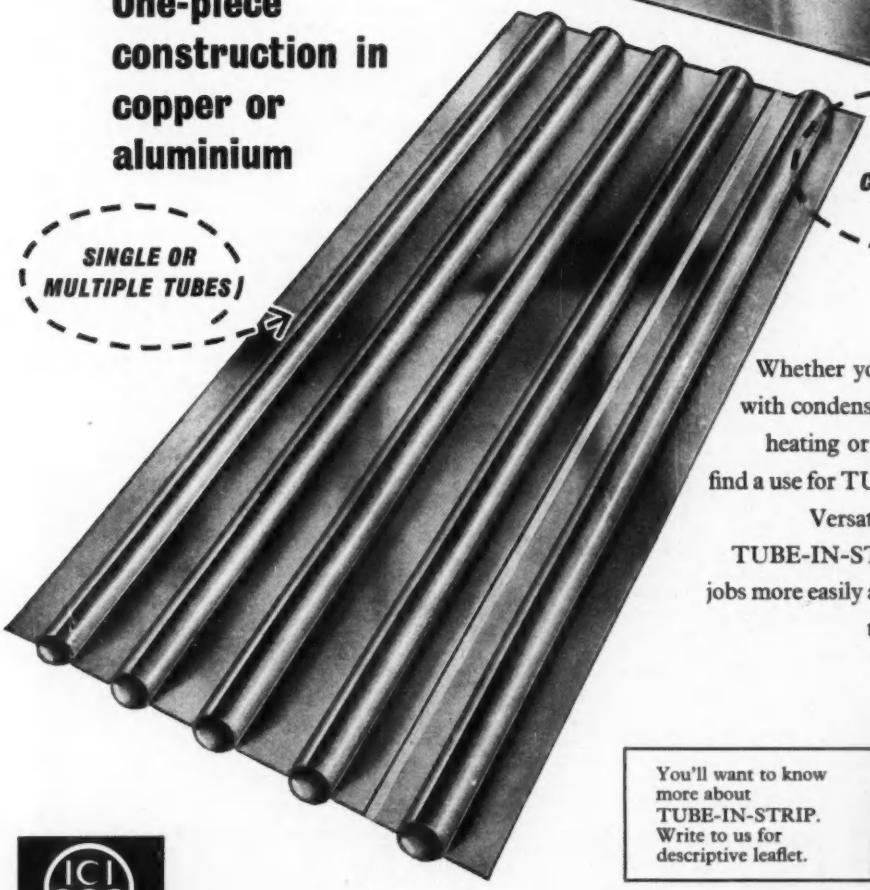

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BUSINESS NOTES

sharing the same factory site as the Building Products Division at Hayes, Middlesex, will act as a separate unit, and has installed what are claimed to be the largest presses in the U.K., together with a considerable quantity of auxiliary equipment, in order to facilitate automatic production. The division is capable of handling any application from its inception to post-production service, and includes a fully operational special dough-moulding compound section, primarily intended to serve the electrical and engineering industries. In addition, a pre-production department has been inaugurated, this being divided into three sections, i.e., estimating, tool design, and preliminary processing, as well as a special development department, which is devoted solely to furthering the uses of reinforced plastics in the building industry and to meeting the varied requirements of the industrial division.

* * *

The iron- and steel-making companies of the **G.K.N. Group,** of which **John Lysaght's Scunthorpe Works Ltd.** and its subsidiary company, **The Scunthorpe Rod Mill Ltd.,** are members, have been amalgamated under the name of the **G.K.N. Steel Company Ltd.,** the new company having acquired the undertakings and assets of these two companies. The business conducted by John Lysaght's Scunthorpe Works Ltd. and The Scunthorpe Rod Mill Ltd. will continue under the name of **Lysaght's Scunthorpe Works (Branch of G.K.N. Steel Co. Ltd.),** under which name all transactions on behalf of the branch will be conducted in future.

* * *

It is announced by the **AABACAS Engineering Co. Ltd.,** of Birkenhead, that their telephone number has now been changed to Birkenhead 6673. In addition, it is announced that their Birmingham representatives are now **B. Clarke & Sons Ltd.,** 1292 Bristol Road South, Longbridge, Birmingham (Tel: Priory 3437).

* * *

To enable their Machine-Tool Division to expand and also to speed up production of Lester injection-moulding machines, which they manufacture under licence in the U.K., **J. Brockhouse & Co. Ltd.** announce that they have acquired the machine-tool works of **Craven Bros. (Manchester) Ltd.,** at Denton, Lancs., together with all their machinery and equipment. Sufficient capacity is also available at this factory, which has a floor space of 70,000 sq ft, for extension of the Lester range of machines, which will include the production of diecasting machines and other interests in plastics now under consideration

H. & E. Lintott Ltd., of Horsham, a member of the **Ayling Industries Group,** has now changed its name to **Lintott Engineering Ltd.**

* * *

A new Reinforced-Plastics Division has been formed by **The English Electric Co. Ltd.,** its address being The English Electric Co. Ltd., Reinforced-Plastics Division, Freckleton Works, Mill Lane, Warton, Lancs. (Tel: Freckleton 521). The range of manufacture includes components for aircraft, traction, and rolling-stock, previously made at the company's Preston Works, as well as numerous other items from various small manufacturing units which have been operating in the group. Although, at this stage, the bulk of production will be used by the group, the new works have been organized for competitive production, enabling reinforced-plastics components to be produced on a commercial basis for outside organizations. The division, which includes a complete preforming and press-moulding manufacturing unit, is equipped to produce a wide range of articles, including large pressure mouldings up to a maximum of 15 × 12 ft, filament-wound tubes, pipes, and pressure vessels.

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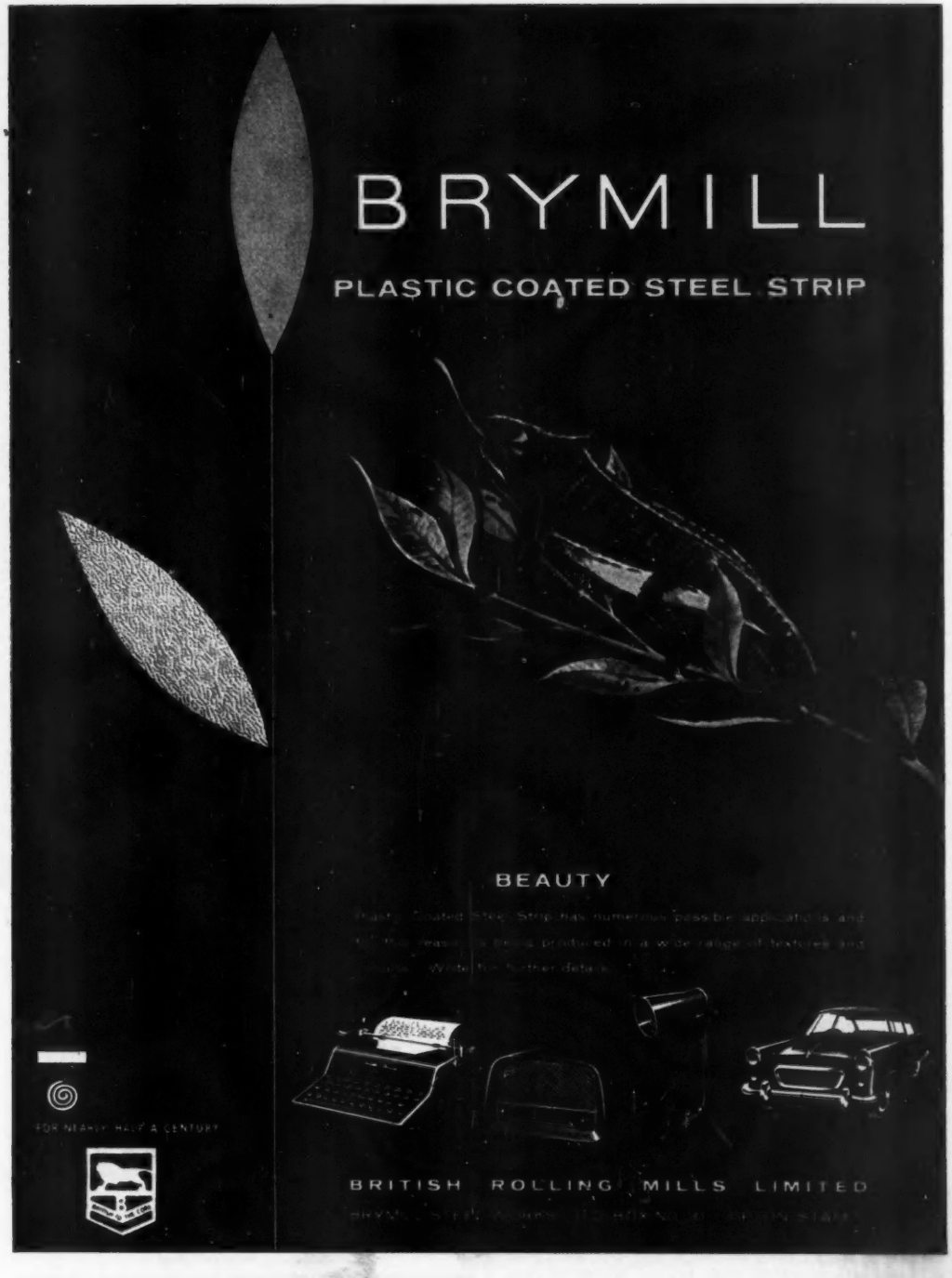
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CONTRACTS

A £50,000 contract for the supply and installation of overhead cranes has been placed with The Wharton Crane & Hoist Co. Ltd., of Reddish, Stockport, by James Booth Aluminium, Ltd., for installation next year in the company's Kitts Green Works, Birmingham, which is now being modernized and re-equipped as part of a £5,000,000 expansion programme. The contract includes an overhead electric travelling crane, four-motor cage-controlled, with a capacity of 110 tons and a span of 62 ft 10 in., fitted with a 5-ton auxiliary hoist. The contract also includes a 5-ton enclosed-type crane on a span of 49 ft, fitted with a telescopic mast and electric slewing gear, and with automatic tongs for handling aluminium ingots, as well as a 30-ton two-point lift, three-motor crane on a span of 91 ft 3 in.

* * *

Davy-Ashmore Ltd. announce that their subsidiary, Davy and United Engineering Co. Ltd., have received an order valued at approximately £300,000 from The Broken Hill Proprietary Co. Ltd. for the design and supply of two 200-ton basic oxygen converter furnaces, to be installed in the company's Newcastle Works, New South Wales, Australia. The contract for these furnaces, which will be manufactured in the Stockton Works of Ashmore, Benson, Pease & Co. Ltd., is believed to represent a new phase in the development of oxygen converter steelmaking, which hitherto has been limited to furnaces of about 100 tons capacity.

* * *

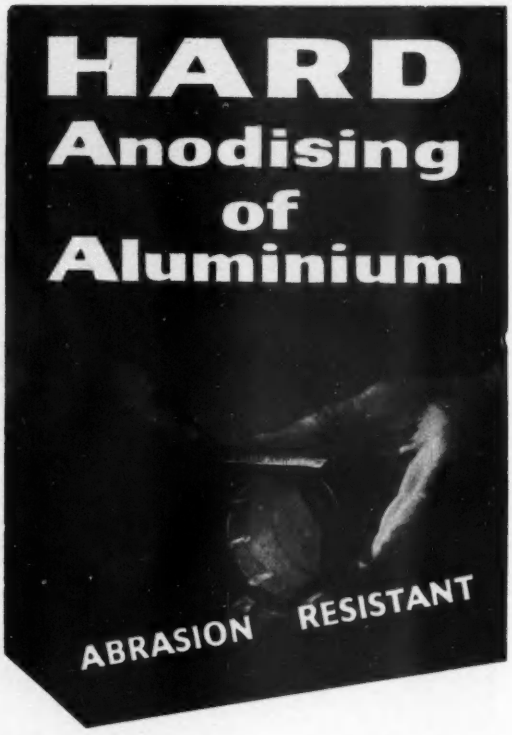
Head Wrightson Processes Ltd., of Yarm and London, a subsidiary of Head Wrightson & Co. Ltd., have been awarded a contract, valued at nearly £500,000, by the Central Electricity Generating Board for the construction of a flue-gas washing plant, part of the extension to Bankside Power Station. This plant is designed to remove more than 95% of the sulphur from the oil-fired boiler flue gases.

* * *

An order worth £10,000 has been received by Temperature Ltd., of London, S.W.6, for the supply, erection, and commissioning of air-conditioning plant for part of the Lancing factory of Eschmann Brothers & Walsh Ltd., who are the first rubber company to install this type of equipment. The equipment will reduce rejects and the lost time at present encountered, by providing stable atmospheric conditions free from excessive heat and humidity during the processing of rubber for catheter tubes and similar medical products. It will virtually eliminate problems associated with the coagulation of rubber stock as a result of humidity and will incorporate an exhaust system for the eleven ovens used in this part of the factory.

* * *

Orders valued at about £500,000 have been received from Russia by the David Brown Machine Tool Division, of Manchester, for precision gear-hobbing machines, ranging in weight from 10 to 120 tons and with gear-diameter capacities from 30 to 150 in. Several of these



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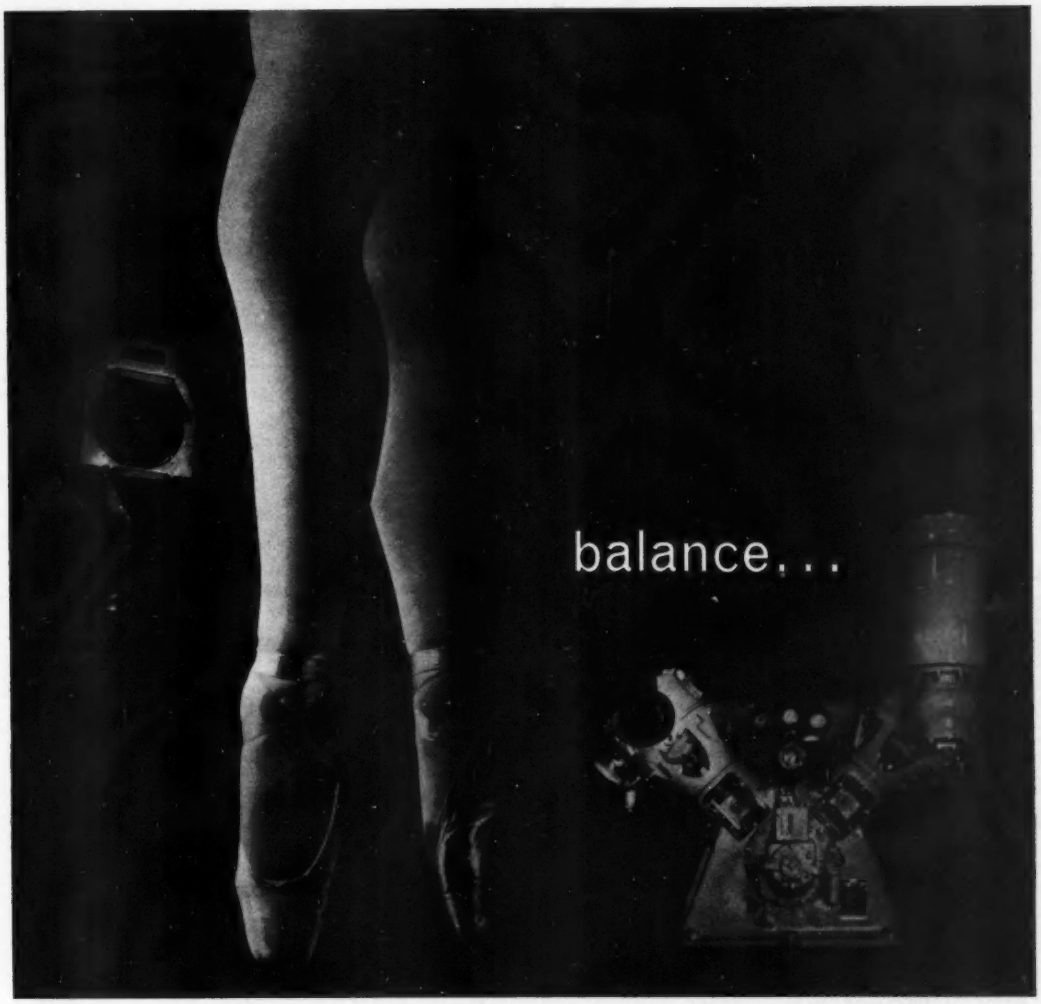

the Joy WN112 stationary compressor

Engineers right on their toes designed the Joy WN.112 compressor, designed it for balance, high-stepping efficiency and the quick precision of a ballet movement. The faultless timing, alignment and complete harmony of the WN.112 make it a machine well worth studying—write for a copy of Publication AD/6—study it well.

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CONTRACTS

machines are equipped with electronic accuracy-control systems developed by the David Brown Machine Tool Division in collaboration with E.M.I. Electronics Ltd., of Hayes, Middlesex, and the National Engineering Laboratory, of Kilbride, Scotland.

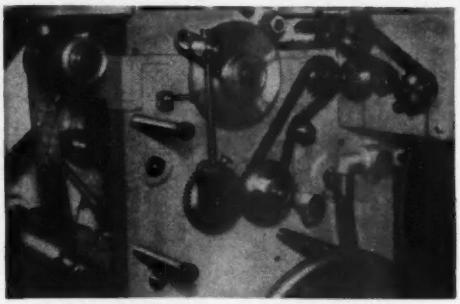
* * *

Australian Electrical Industries (Pty.) Ltd. have ordered from the Heavy Plant Division of Associated Electrical Industries Ltd., of Rugby, synchronous and squirrel-cage induction motors valued at over £100,000 for driving compressors in a new oxygen tonnage plant in New South Wales, to be supplied by Linde Eismaschinen A.G., of Munich, for producing oxygen in large quantities for steel manufacture. Three 3500-hp synchronous motors will be used to drive centrifugal air compressors, while two 2200-hp synchronous motors will drive centrifugal oxygen compressors, and two 1500-hp squirrel-cage induction motors will drive reciprocating oxygen compressors. Starting equipment and switchgear are included in the order.

* * *

Orders for the 8700 nautical miles of newly developed submarine telephone cable and 335 submerged repeaters (amplifiers) required for the largest telephone-cable project yet undertaken have been placed by the Pacific Cable Management Committee with two British companies, i.e., Standard Telephones and Cables Ltd. and Submarine Cables Ltd. The total value of the orders is approximately £18,000,000 and, under the conditions of the contract, as much as possible of the raw material required for the cable is to be supplied from Australia and Canada. This Commonwealth submarine telephone cable will span the Pacific Ocean, linking Australia, New Zealand, and Canada and its completion is scheduled for the middle of 1964. The cable will have a capacity of 80 high-grade telephone channels and, in addition to public telephone service, will provide public telegraph, photo-telegraph, and telex circuits, together with facilities for leased private circuits for all types of telecommunications services and broadcast-programme channels. It will connect, via Canada, with a similar cable to be laid this year between Canada and the U.K., and will therefore open up greatly improved services between Europe and New Zealand and Australia.

RENOLD Sprag Clutches



transmit more torque for size and weight than any other clutch

for *INDEXING

as illustrated on this toffee wrapping machine. The sprag clutch is used for indexing the paper feed drives which also employ Renold ·375" pitch simplex roller chain.

***Renold sprag clutches index with speed and accuracy—and to infinite graduations—limited only by the precision of the other components of the machine.**

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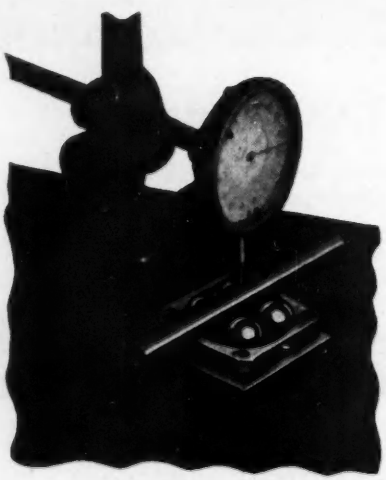

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THE DOUBLE SEALING EMPIRE RUBBER GROMMET

infinitely accommodating in use:
considerably reduces range of sizes
because the same grommet can be used with
several plate thicknesses or cable sizes

PAT. APP. No. 5255/59

This newly developed self-conforming grommet, because it is immediately self-locking against the elements, is the solution to many of an engineer's sealing problems.
Any one size will not only accommodate itself to a variety of mounting plate thicknesses, but (designed for cable or control rod) will take these in a variety of sizes and be weather-, water- and dust-proof at a variety of angles to the cable or rod.

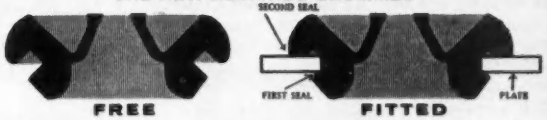
Because of its capacity to conform to many varying requirements, it enables a workshop stock range of grommets to be reduced to perhaps one tenth of that at present maintained.

THE NEW BLIND GROMMET

FREE

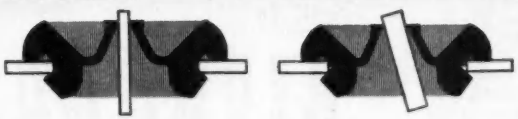
Note how when sprung into position the grommet provides a perfect double seal by its own permanent pressures. The angled groove also creates a tight pressure hold on the metal plate.

THE NEW DESIGNED GROMMET



FREE FITTED

In the cable grommet variety the same double pressure seal is created, allied to tight seal on various diameters of cable. This new grommet gives sound sealing at *all* vital points.



A useful feature of this cable grommet is that by reason of the designed taper of the cable entry and the flexibility of the web, a considerable angle of cable entry and a variety of cable size are possible. This avoids necessity for special grommets with angled bores.

In the conventional grommet, only one thickness of plate and only one size of cable can be accommodated. No effective seal is afforded by the parallel groove.

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PERSONAL

Mr. A. Nadin, A.M.B.I.M., A.M.I.W.M., general manager of Brayshaw Furnaces Ltd. and Brayshaw Tools Ltd., of West Gorton, Manchester 12, has been appointed a director of both these companies.

* * *

Mr. P. R. Armitage, A.M.I.Loco.E., has been appointed manager of the Traction Division of The General Electric Co. Ltd., in succession to **Mr. W. D. Morton,** who was recently promoted to the position of assistant general manager of the company's Witton Works.

* * *

It is announced that **Mr. N. A. Morling,** who was appointed a director of Ferodo Ltd. in July 1960, will succeed **Mr. G. S. Sutcliffe** as chairman. Mr. Sutcliffe will resign his directorship of Ferodo Ltd. and will assume the chairmanship of three other companies in the Turner and Newall Organization, i.e., Turner Brothers Asbestos Co. Ltd., J. W. Roberts Ltd., and Glass Fabrics Ltd., this appointment having been held by Mr. Morling for the past four years.

* * *

Mr. L. J. Garibaldi has been appointed manager of the Steam and Gas Turbines Division of The English Electric Co. Ltd. at Rugby, following the retirement at his own request of **Mr. A. Friswell, M.I.Mech.E.,** general manager of the Steam Turbine Division. Mr. Garibaldi, who has been contracts manager of this Division since 1955, will be responsible for all commercial activities connected with turbines and for the co-ordination of policy in engineering, sales, and contracts.

* * *

It is announced that **Mr. R. Lewis Stubbs,** director of the Zinc Development Association, has been appointed director-general of the Lead Development Association and of the Zinc Development Association. As such, he will be responsible for the overall direction and expansion of the work of both Associations, and will represent them at international meetings. Each Association will, however, continue to function separately, and general managers for both will shortly be appointed.

* * *

John Brown Land Boilers Ltd. announce that **Mr. H. M. Gregory** (general manager, works and construction) and **Mr. J. D. Williams, B.Sc.,** (chief engineer) have been appointed directors. **Sir James McNeill** and **Mr. T. Mensforth** have resigned their directorships. In addition, **Mr. P. B. Low, C.A.,** has been appointed chief accountant, in succession to **Mr. I. M. Graham, C.A.,** who has been appointed a director and secretary of John Brown (S.E.N.D.) Ltd.

* * *

The Asquith Machine Tool Corporation announce that **Mr. J. Atherton** has joined their subsidiary company, William Asquith Ltd., as a director and chief engineer. **Mr. A. Johnson** has relinquished his position as chief

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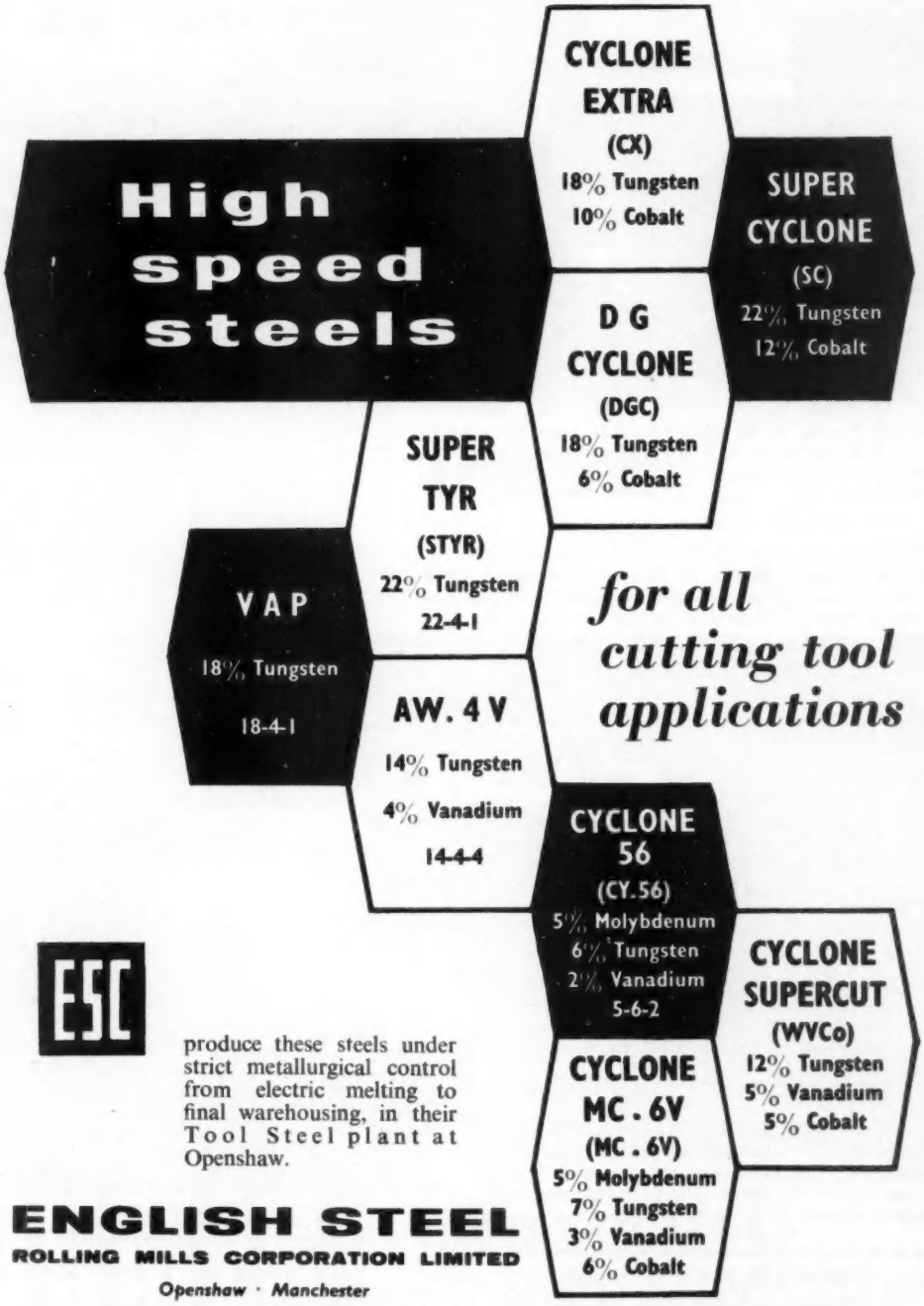
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PERSONAL

engineer of William Asquith Ltd., but is retaining his seat on the board, and will act as consultant and will concern himself with general development work for the group.

* * *

Mr. E. O. Charlton, A.M.I.Mech.E., has been appointed manager of the London office of W. H. Allen Sons & Co. Ltd., of Bedford, in succession to **Mr. F. A. B. Andrews,** who has retired after 53 years of service with the company.

* * *

As announced by the Darwins Group Ltd., of Sheffield, **Captain J. K. Hamilton, R.N.,** has been appointed a director of their subsidiary company, the Sheffield Forge & Rolling Mills Co. Ltd., of Millsands, Sheffield.

* * *

Following their acquisition by Crane Ltd., of London and Ipswich, Rhodes, Brydon & Youatt Ltd., of Stockport, Cheshire, announce that **Mr. W. Latta** has been appointed director and general manager of the latter company.

* * *

Metal Industries Ltd. announce the appointment of **Mr. R. J. F. Howard** as Director of Marketing, in which capacity he will be primarily concerned with the co-ordination of the marketing activities of the electrical companies within the M.I. Group. Mr. Howard was previously a director of Lancashire Dynamo Electronic Products Ltd. He remains a non-executive director of this company and also joins, in a similar capacity, the boards of five other M.I. subsidiaries, i.e., Brookhirst Igranic Ltd., Lancashire Dynamo & Crypto Ltd., Foster Transformers Ltd., J. G. Statter & Co. Ltd., and Lancashire Dynamo Nevelin Ltd.

* * *

Mr. J. C. Budd has been appointed chairman of The Manganese Bronze & Brass Co., Ltd., of London, E.C.2, in succession to **Mr. J. C. Colquhoun,** who has retired. **Mr. R. Dennis Poore** has been appointed a director of the company.

* * *

It is announced by the A.P.V. Co. Ltd. that **Mr. P. W. Seligman** has been appointed deputy chairman, while retaining his present position of managing director, and that **Mr. H. P. N. Benson** has also been appointed managing director.

COMMANDER J. R. PATTERSON

We announce with deep regret the death of Commander J. R. Patterson, O.B.E., D.S.C., R.N. (Rtd.), technical secretary of The Parsons and Marine Engineering Turbine Research and Development Association (Pametrada).

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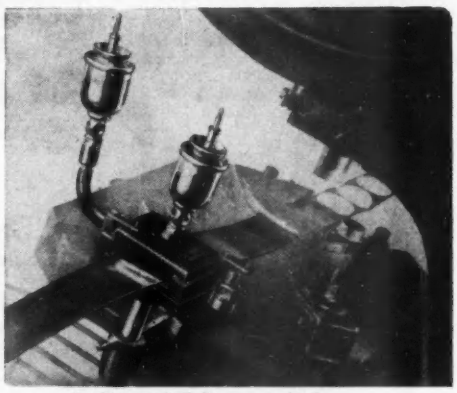

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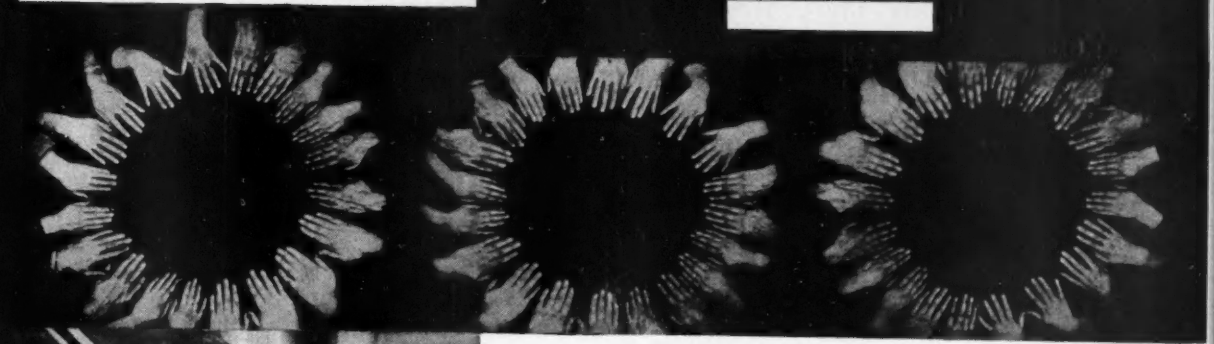

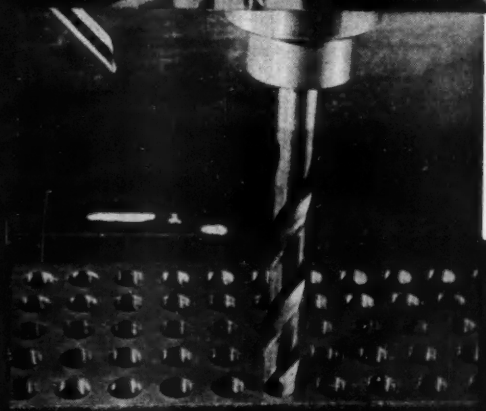

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NEWS ROUND-UP

Woolwich Polytechnic Computer Centre

The Stantec "Zebra" automatic electronic digital computer recently installed at the Woolwich Polytechnic, London, is a general-purpose computer of medium size, suitable for mathematical, scientific, engineering, and statistical calculations, and for commercial, financial, and industrial applications. Woolwich Polytechnic is amongst the very few establishments of further education to possess a computer, and a large library of problems, already programmed, is available to users.

The Computer Centre, which is established in the Mathematics Department of the Woolwich Polytechnic, will be used for the following purposes:—

(1) As a service to users in industry and commerce, who are invited to discuss their problems with the computer staff and to use time on the computer, a moderate fee being charged for this latter service. In this connection, the Mathematics Department will welcome visits from anyone interested and is prepared to arrange courses on programming methods, according to demand.

(2) For the training of students in the use of digital computers. It is intended that every student of the Polytechnic who is studying for a B.Sc. degree in mathematics, physics, chemistry, engineering, or economics, and every student studying for a Diploma in Technology or a Higher National Certificate with endorsements, will have an opportunity to write programmes for and to operate the computer. This is of particular importance because, in the next five years, the number of computers in operation in the U.K. may well quadruple and it will therefore become necessary for an increasing number of scientists and technologists to have some knowledge of computer techniques.

(3) As an aid to research by members of the staff and post-graduate students of the Polytechnic and other educational establishments.

European Symposium on Space Technology

Primarily intended to bring together engineers and scientists, with a view to discussing the possibility of formulating a joint programme of space research, the First European Symposium on Space Technology, organized by the British Interplanetary Society, will be held in the Council Room of the Federation of British Industries, 21 Tothill Street, London, S.W.1, between June 26 and 28, 1961. The Symposium will be open to participation by countries in Western Europe, particularly those who belong to the Organization for European Economic Cooperation, but it is also envisaged that Commonwealth countries, especially Australia and Canada, will be concerned in any programme decided upon.

The conference will have heavy industrial overtones and will discuss the most fruitful lines of approach, bearing in mind the resources in men and materials available for the participating nations. In addition to consideration of technical projects, matters of finance and organization will be dealt with, leading eventually to final

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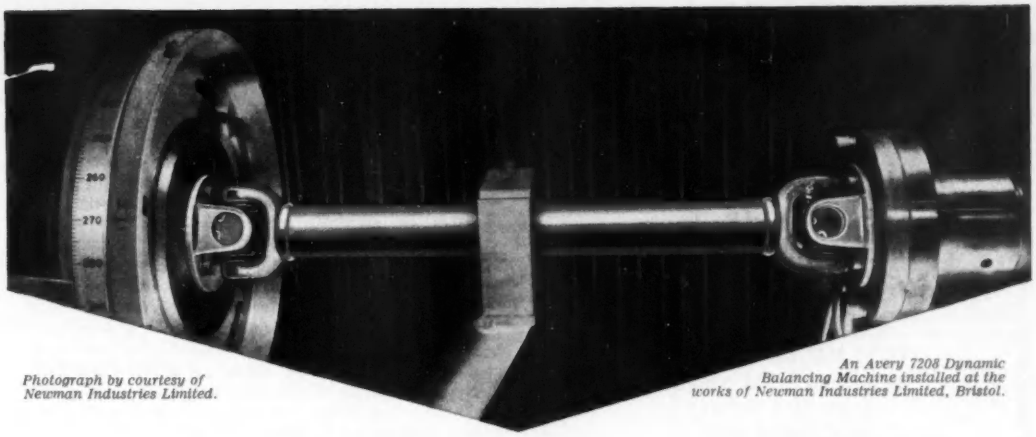

Photograph by courtesy of Newman Industries Limited.

An Avery 7208 Dynamic Balancing Machine installed at the works of Newman Industries Limited, Bristol.

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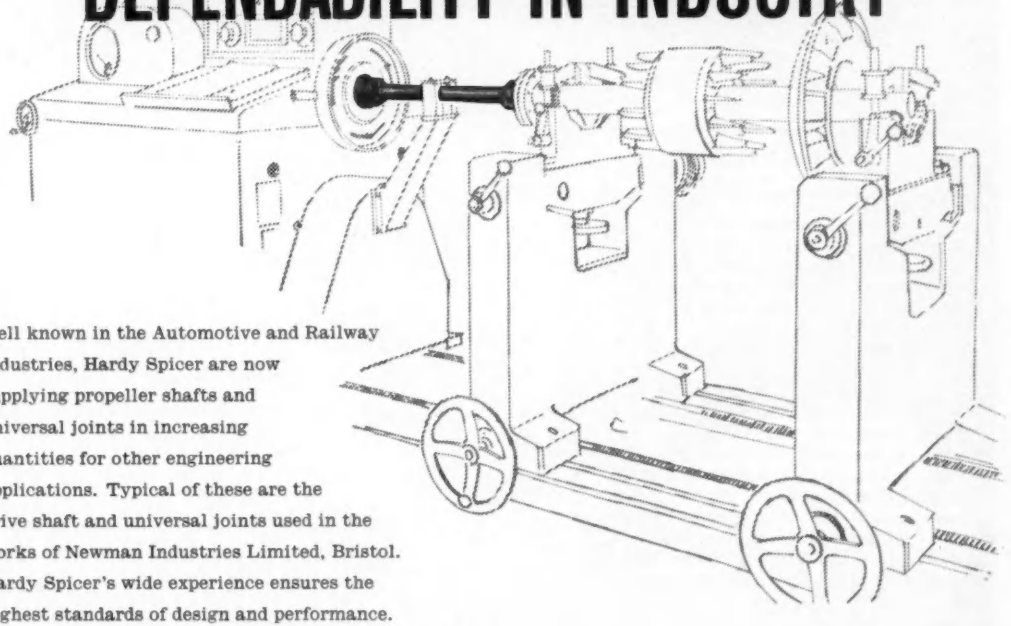

Well known in the Automotive and Railway Industries, Hardy Spicer are now supplying propeller shafts and universal joints in increasing quantities for other engineering applications. Typical of these are the drive shaft and universal joints used in the works of Newman Industries Limited, Bristol. Hardy Spicer's wide experience ensures the highest standards of design and performance. Please write for further details and illustrated leaflets.

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decisions and recommendations for future consideration. It is hoped that this may lead to an expanding programme of space exploration, undertaken on the widest possible international basis, and the closest possible collaboration with the U.S.A. and, if possible, the U.S.S.R., is also envisaged.

It is clear that the cost of a major space programme is very high, and this is naturally a matter for careful consideration, even though the ultimate rewards may greatly exceed the expenditure involved. Nevertheless, there are limitations on the number of personnel and the abilities of those who can contribute effectively to this subject, and it is therefore more than ever necessary to conceive a carefully prepared programme which does not involve duplications of the efforts of other countries.

Further particulars and information are obtainable from Mr. L. J. Carter, Secretary, British Interplanetary Society, 12 Bessborough Gardens, London, S.W.1.

The New HSBT Turbine Factory at Hucclecote

Covering approximately 200,000 sq ft, fully equipped with the most modern machine tools and services, and incorporating comprehensive research, development, and test facilities, the new turbine factory recently constructed for Hawker Siddeley Brush Turbines Ltd. at Hucclecote, Gloucester, is undoubtedly one of the finest of its kind in Europe for the manufacture of medium-size turbines. The factory, which is built on the site of the Gloster Aircraft Works, is fully equipped for the production and testing of steam turbines of both axial- and radial-flow types, gas turbines, gas expansion turbines, turbo-chargers, and compressors.

Since a large portion of the output is for export, special attention has been given to the provision of test facilities. Thus, for steam turbines, boiler plant of sufficient capacity is available to enable the largest machines in the range manufactured to be proved mechanically and, in those cases where electrical loads are required, test facilities permit handling loads up to about 5000 kW. A permanent test condenser is installed but, where necessary, machines can be run with their own condensers. In the case of gas combustion turbines, two test-beds are provided, each being capable of testing machines up to 10,000 hp. With regard to gas expansion turbines, the majority of these machines operate with free-piston gasifiers of the Sigma/Pescara type, each gasifier producing an effective 1000 hp. A total of four gasifiers (type GS.34) is provided in the gasifier test-house, making the equivalent of approximately 4000 hp available for test. This power is sufficient for the mechanical proving of the larger machines up to about 10,000 hp. In addition, this equipment can be used when testing gas expansion turbines for the chemical and oil industries when pressure and temperature conditions permit.

Research and development facilities include test cells for turbochargers, a mechanical laboratory, a vibration laboratory, and component fatigue testing on specially designed machines or using standard vibrators. Facilities are also available for the investigation of noise problems, including equipment for the generation, analysis, and recording of sound both in the laboratory and in the field. In addition, balancing of rotating assemblies is carried out on special machines, the largest of which is capable of handling rotors weighing up to 22,000 lb, while a fully equipped metallurgical laboratory makes it possible to carry out metallurgical and chemical examinations of the raw materials used in the company's products and to investigate any problems of a metallurgical and chemical nature arising during their service life. Provision is also made for the mechanical testing of metallic materials and the non-destructive testing of components by means of magnetic crack-detection and ultrasonic techniques.

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A candidate for the Fellowship should normally have had two or three years' research or industrial experience. He should have an Honours Degree or equivalent qualification and be acceptable to the University of Birmingham as a research fellow.

The Wilmot Breeden Fellow would engage in an enterprise of such a character as to require the facilities both of the University and the Company, his time being spent at both. His enterprise may have the character of Scientific Research, Design, Development, a combination of some or all of these, or in some other way to be appropriate to the activities of Wilmot Breeden. The Company is especially concerned with Mechanisms, Electro-Chemistry, Metal Finishing, Metallurgy, Metal Formation, Hydraulics, Electronics. Full details may be obtained on application to the Secretary, Wilmot Breeden Fellowship Committee, Amington Road, Birmingham 25.

Final applications must be received by the Secretary before 1st May 1961.

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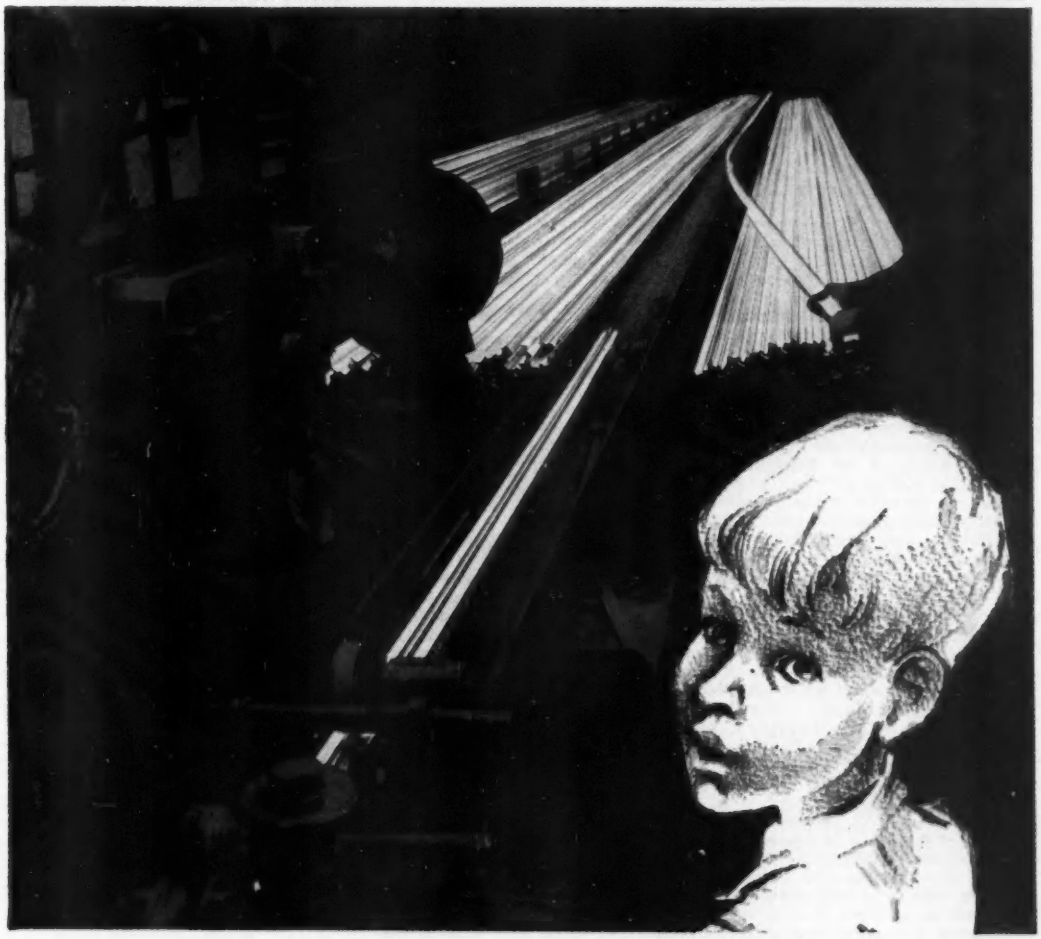

NEW TECHNICAL BOOKS

Advanced Dynamics for Engineers. By Glenn L. Downey and Gerald M. Smith. 362 pp., 474 illustrations. Publishers: International Textbook Company, Scranton 15, Pa , U.S.A. Price: $9.50.

Intended for senior-level undergraduate engineering students, this outstandingly well-produced book is an advanced presentation of engineering dynamics, in which emphasis throughout is laid on the derivation and solution of differential equations of motion, with vector analysis used in many cases as a rigorous and efficient method of analysis. The authors, who are Associate Professors of Engineering Mechanics at the University of Nebraska, write interestingly and lucidly and include in each chapter a considerable number of typical problems, of varying degrees of difficulty, selected to illustrate the basic principles and the application of theory to actual engineering problems.

After discussing the basic concepts of the subject by introducing the reader to dimensional analysis, vector analysis, and complex vectors, the kinematics of relative motion, with an introduction to vector-analysis approach, are covered, followed by the derivation and solution of differential equations of motions and including such topics as motion in a resisting medium, the motion of projectiles, and the balancing of rotating and reciprocating masses. The principles of kinetic and potential energy, as related to rigid and elastic two-dimensional systems and rigid three-dimensional systems, are then integrated, with Castigliano's theorem and generalized co-ordinates introduced as important tools in this connection. The impulse-momentum approach is then applied to systems of constant and variable mass and moments of inertia, with applications in such fields as jet propulsion and gyroscopic motion, and Euler's equations are developed in the study of motion about a fixed point.

A considerable portion of the book is devoted to a study of vibrations and periodic motion in various systems, including those with multiple degrees of freedom. The theory of vibration is integrated with several basic principles of electrical engineering, such as integrating circuits, differentiating circuits, and Lissajous figures on an oscilloscope screen, while the analysis of periodic motion includes the derivation and discussion of Kepler's laws in relation to planetary motion and earth satellites. Finally, because of the increasing use of computers, the basic theory of the analogue computer is discussed, vibration systems with specific physical quantities being used to illustrate computer set-up, thus acquainting students with magnitude scaling, time scaling, component selection, and potentiometer settings, and enabling them, if a computer is available, to be given some experience on computers.

The Autodyne—A New Electrical Machine. 2nd edition. By Otto Benedikt. Translated by G. Téglás, 193 pp., 130 illustrations. Publishers: Pergamon Press Ltd., Headington Hill Hall, Oxford. Price : 45/–.

As Professor Tustin, of the Department of Electrical Engineering, Imperial College, points out in his preface to this revised edition in English of Professor Benedikt's book, the Autodyne is a novel machine which "is a very distinctive new member of the broad family of rotary amplifiers. It has the mark of all true inventions—an essential simplicity. It springs from the union of a firm grasp of the mode of operation of a rotary converter, with a lively appreciation of the possibilities of 'feedback' and gives us, with a single machine, a means to obtain control of any quantity that can be made to depend on a direct current, using the ordinary fixed frequency a.c. power supply as the source of energy. There is no doubt that the basic idea is capable of many variants and of further development."

In this book, which is well translated and excellently produced, Professor Benedikt, of the Technical University, Budapest, Hungary, who devised this ingenious new electrical machine, takes a physical-quantitative approach to his subject, in preference to a mathematical-quantitative approach, and his treatment of transient phenomena is deliberately restricted, enabling an exhaustive investigation to be made of such important problems as to whether the principle underlying the operation of the Autodyne is suitable for ensuring reliable functioning, whether the control afforded is sufficiently accurate and extends over a sufficiently wide range, whether its static and dynamic communication is sufficiently good, whether the power factor is satisfactory and the efficiency is high enough, whether the converter operation can or cannot be inverted, and whether the shape of the individual parts and the technology of their manufacture do not involve undue difficulties.

In short, this excellent book, dealing as it does with a new machine of considerable industrial potential, will undoubtedly prove of exceptional interest and value to all electrical engineers and scientists.

Engineering Drawing for Students. By Richard Marriott. 80 pp., 156 illustrations. Publishers: Methuen & Co. Ltd., 36 Essex Street, London, W.C.2. Price: 6/–.

Fundamentally intended as a textbook for students in Engineering Drawing, particularly those preparing for the General Certificate of Education at "O" level and for other examinations of a similar standard in this subject, this excellent little book nevertheless covers its subject beyond the usual examination requirements, thereby giving as complete a picture as possible

Despite its small size, the book deals with all important aspects of the subject concisely, yet lucidly. Various types of projection are explained, and suggestions are given to help in developing the ability to make simple freehand drawings. The drawing exercises in machine parts have been arranged conveniently in groups, centred around particular topics, each group being introduced by an illustration and a very brief description of the engine, machine, or apparatus on which the exercises are based, thus enabling the student to revise his background knowledge and appreciate the function of various specific machine parts. In addition, certain additional topics have been included, such as the elementary treatment of cams and involute gear teeth.

South African Mining and Engineering Year Book, 1960-61. Edited by S R Potter. 835 pages. Published by the South African Mining Journal Syndicate, Ltd., Balgownie House, 66 Commissioner Street, Johannesburg, South Africa. Price: 84/–.

This latest edition of the South African Mining and Engineering Year Book, which incorporates the Rhodesian Mining Year Book, constitutes a *vade-mecum* of information on mining and engineering activities in South Africa and Rhodesia. The emphasis is, of course, laid on mines and mining, with sections devoted to Rand mining and financial groups, independent companies, diamond companies, colliery companies, base-mineral companies, and industrial and commercial companies. In addition, comprehensive information is given with regard to the range of equipment purchased by the mines, to Government departments and public bodies, and to consulting engineers and geologists in the Union and in Northern and Southern Rhodesia. Other sections include an alphabetical list of the principal engineering firms in these countries, a buyers' guide to mining and engineering specialities, and lists of mining, municipal, railway, and industrial buyers, of British and overseas manufacturers exporting to the Union and the Rhodesias, and of overseas manufacturers represented in the Union and Rhodesias.

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2. Spring Pins

An illustrated 4-page folder contains particulars of self-locking spring pins made of carbon steel, corrosion-resistant steel, or beryllium copper. The use of the spring pins, which can replace cotter pins, keys, axles, hinge pins, pivots, etc., eliminates tapping, reaming, milling, and peening operations in metal assemblies. In addition, they can also be used for fastening nylon, bakelite, hard rubber, and other materials.

3. Weldnuts

Developed for all types of projection welding equipment, a range of weldnuts is presented in an 8-page brochure. The weldnuts are manufactured from high-quality low-carbon cold-forming steel and are eminently suitable for accurate and quick positioning by hand or mechanical means in punched or drilled holes.

4. Solderless Terminals and Connectors

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Equally suitable for small batches and long production runs, and providing high production rates in the manufacture of a wide variety of gears, wormwheels, and worms, a range of universal hobbing machines is introduced in an 8-page brochure. The machines are designed with a built-in differential and are capable of cutting any number of teeth from six upwards. For the production of spur or helical gears, splines, serrations, and sprockets, either climb or conventional hobbing techniques can be employed without the necessity of any machine adjustments or attachments.

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9. Copper and Copper-Alloy Rods and Sections

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An illustrated 58-page catalogue contains particulars of performance and operation of a range of worm reduction-gear units and information on the speed ranges, capacities, efficiencies, mounting arrangements, etc., of the gears. In addition, tables of service factors and load characteristics and notes on contact marking and wormwheel adjustment, as well as useful worm-gear selection charts, are included.

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Information is presented in a 32-page catalcgue on a range of alloy tool steels, such as hot die, tungsten, chrome, and oil-hardening alloy tool steels; non-shrinking and nickel-chrome steels; and special cold-pressing vanadium and carbon tool steels. Details of heat treatment and composition are given, and temperature conversion and hardness comparison tables, as well as notes on finishing allowances and special treatments, are also incorporated.

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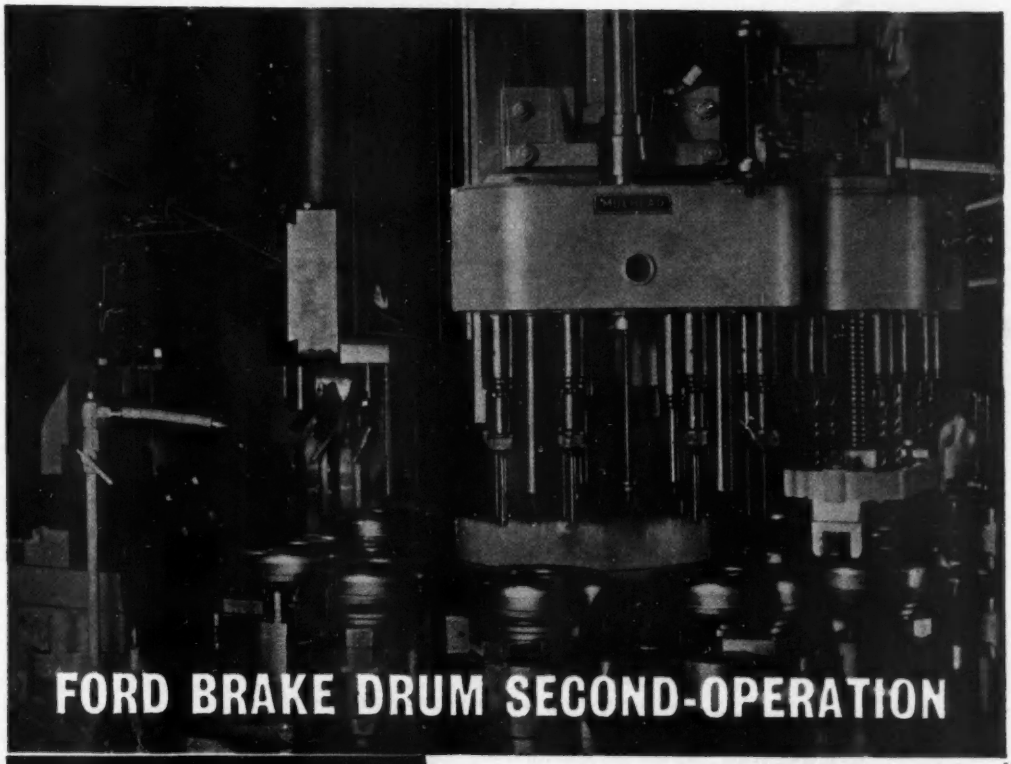

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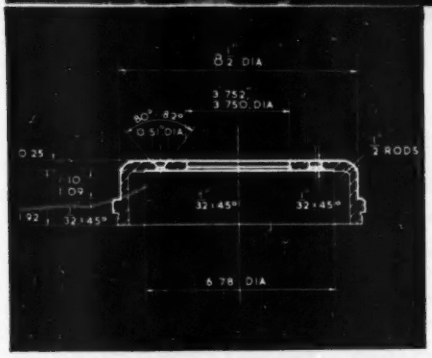

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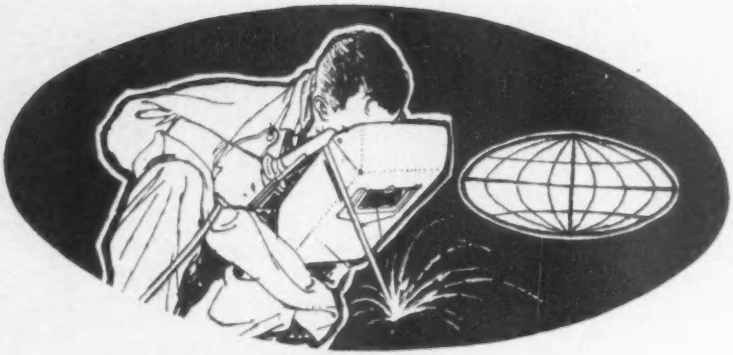

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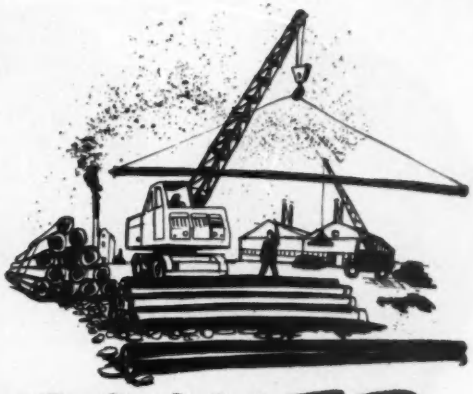

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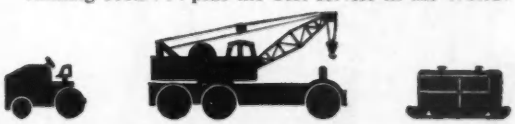

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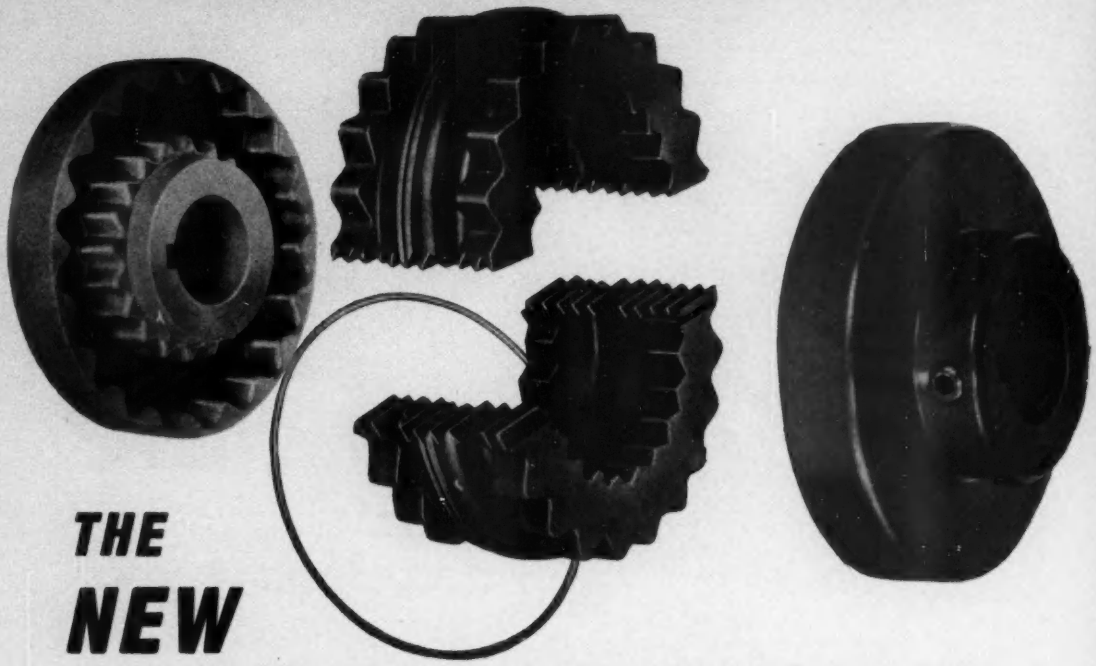

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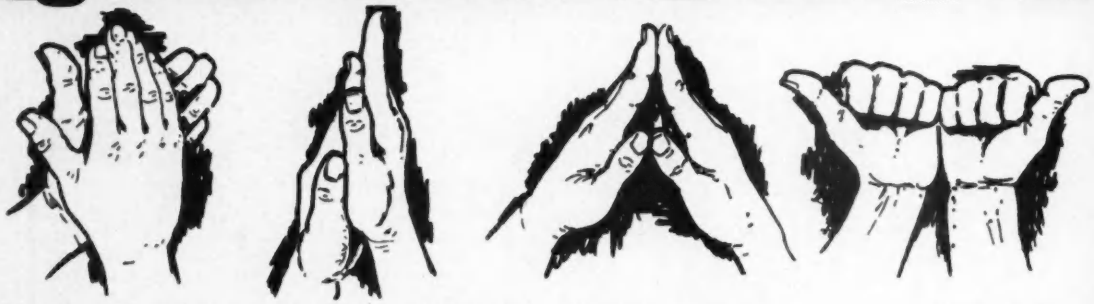

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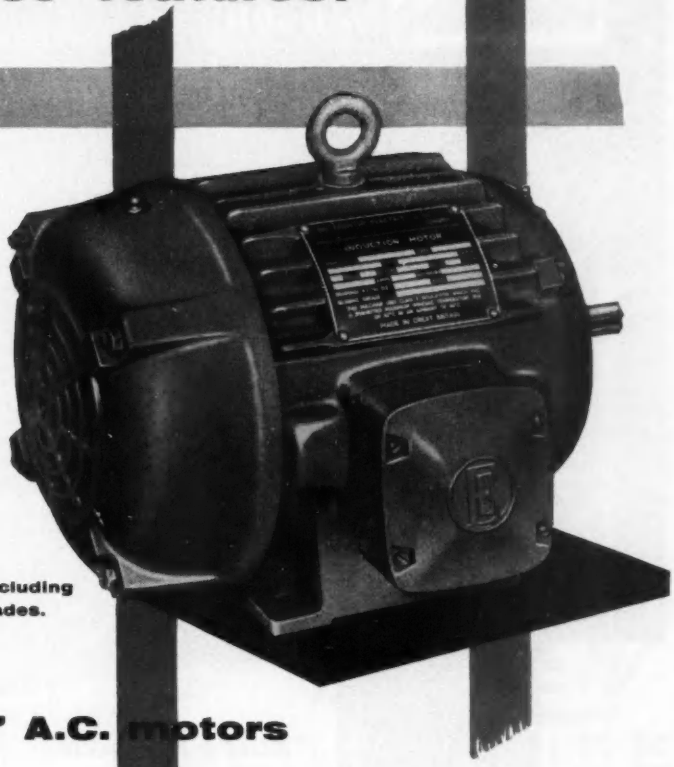

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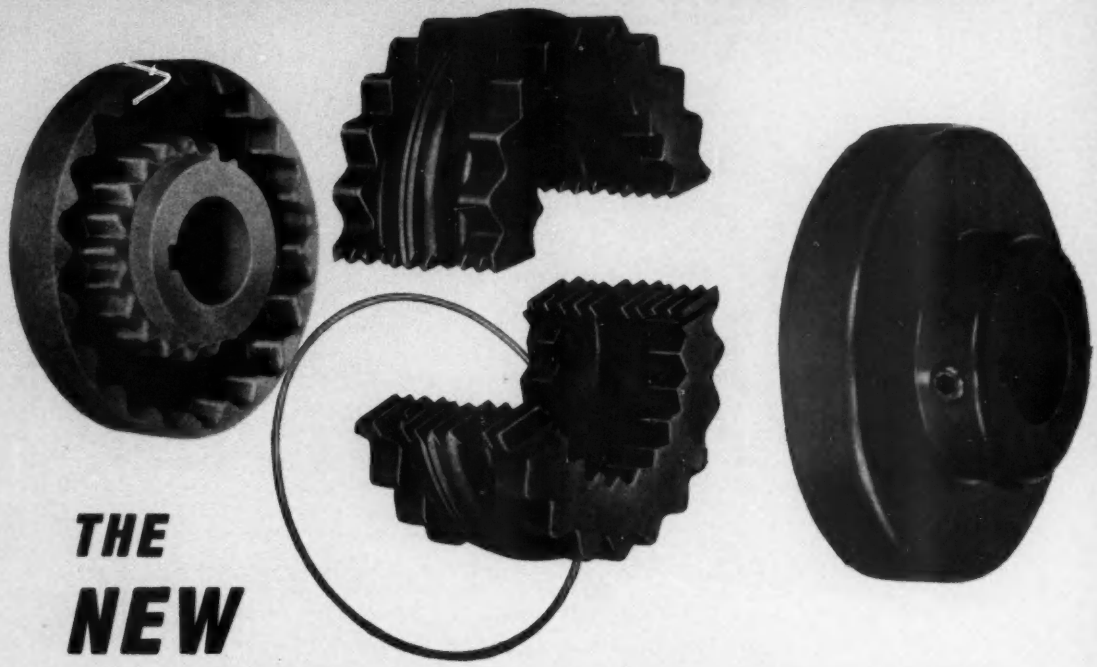

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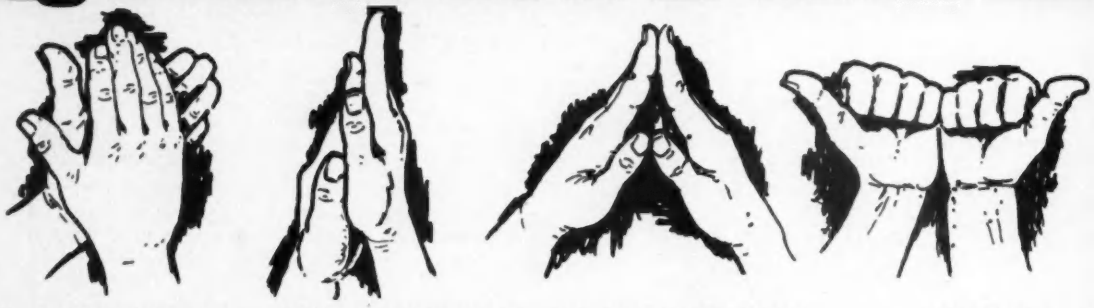

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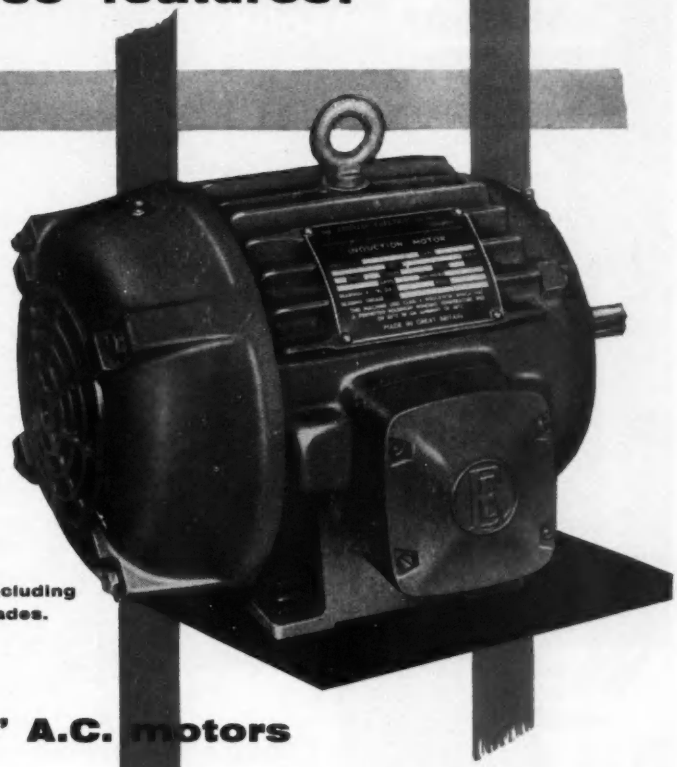

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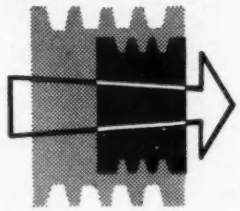

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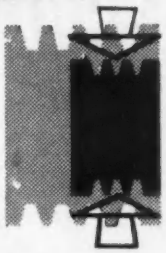

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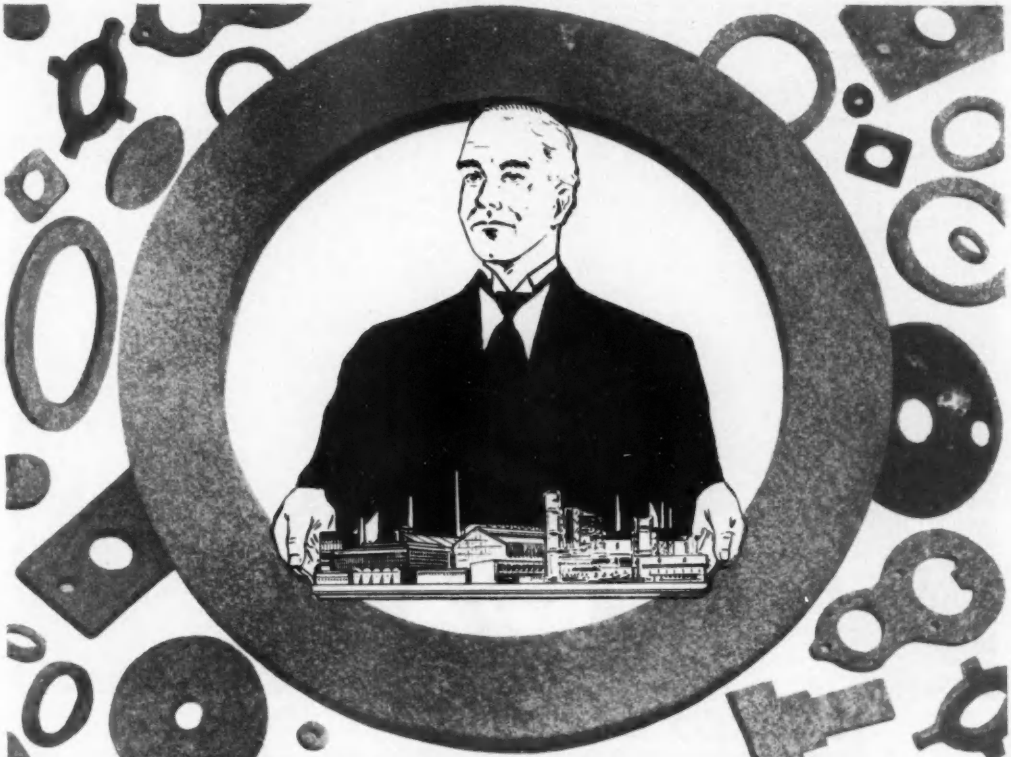

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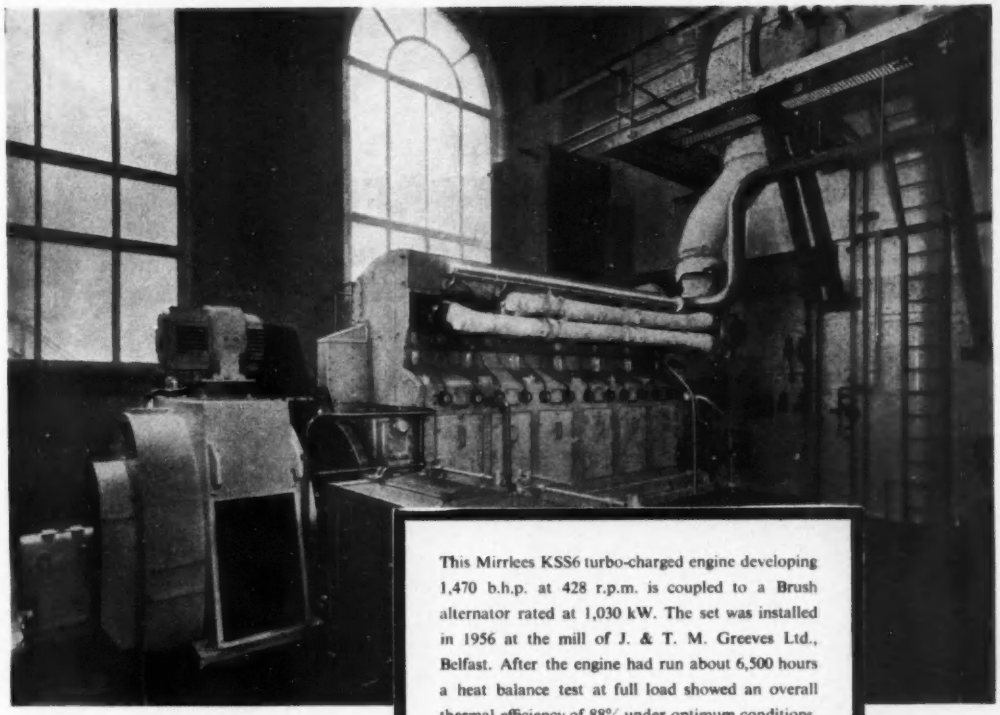

This Mirrlees KSS6 turbo-charged engine developing 1,470 b.h.p. at 428 r.p.m. is coupled to a Brush alternator rated at 1,030 kW. The set was installed in 1956 at the mill of J. & T. M. Greeves Ltd., Belfast. After the engine had run about 6,500 hours a heat balance test at full load showed an overall thermal efficiency of 88% under optimum conditions.

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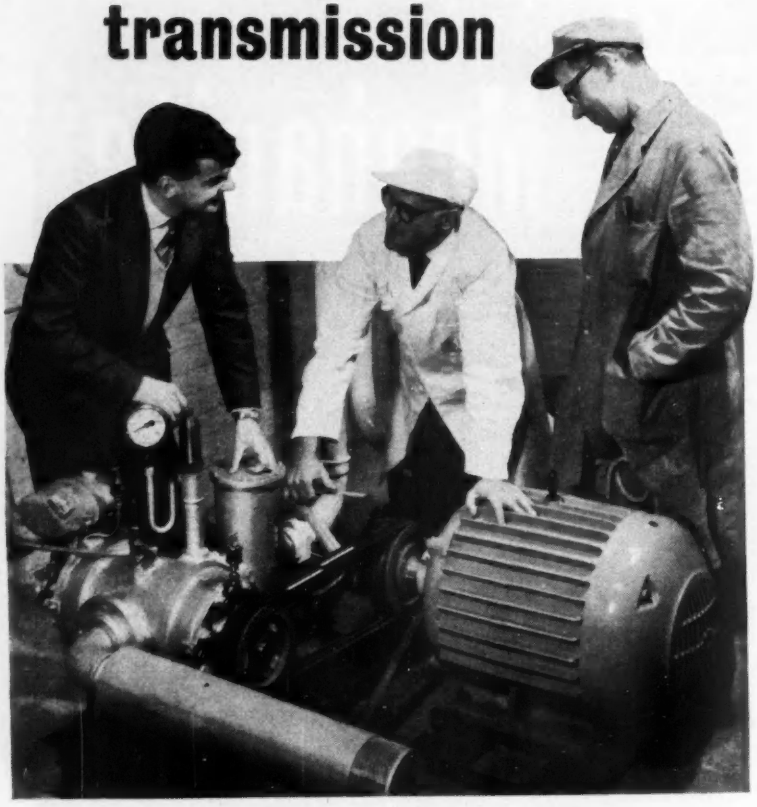

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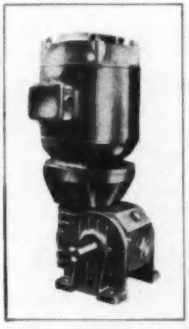

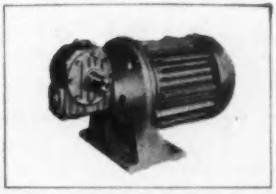

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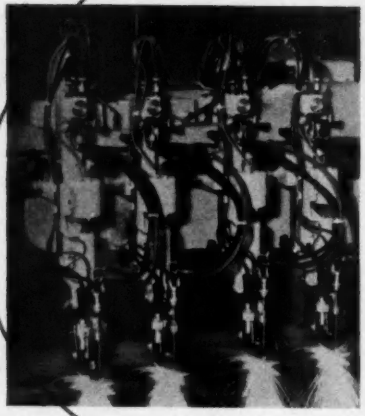

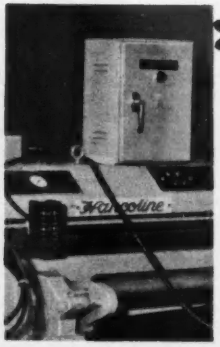

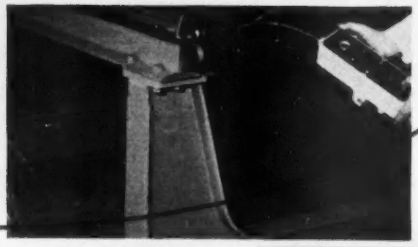

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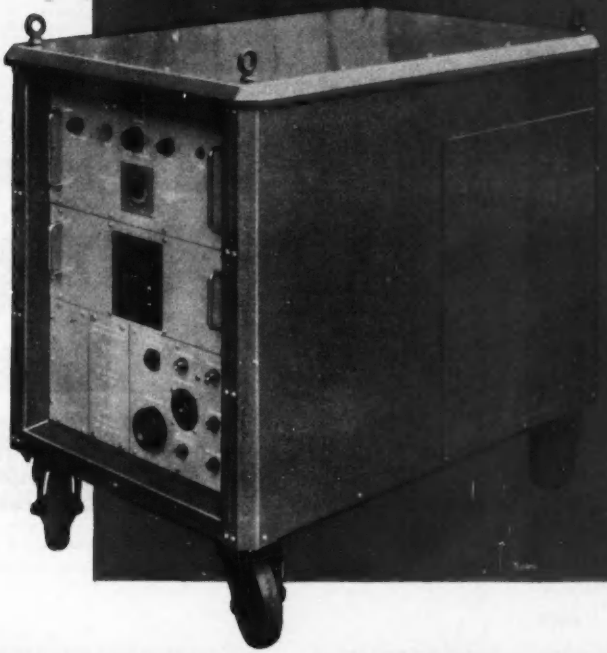

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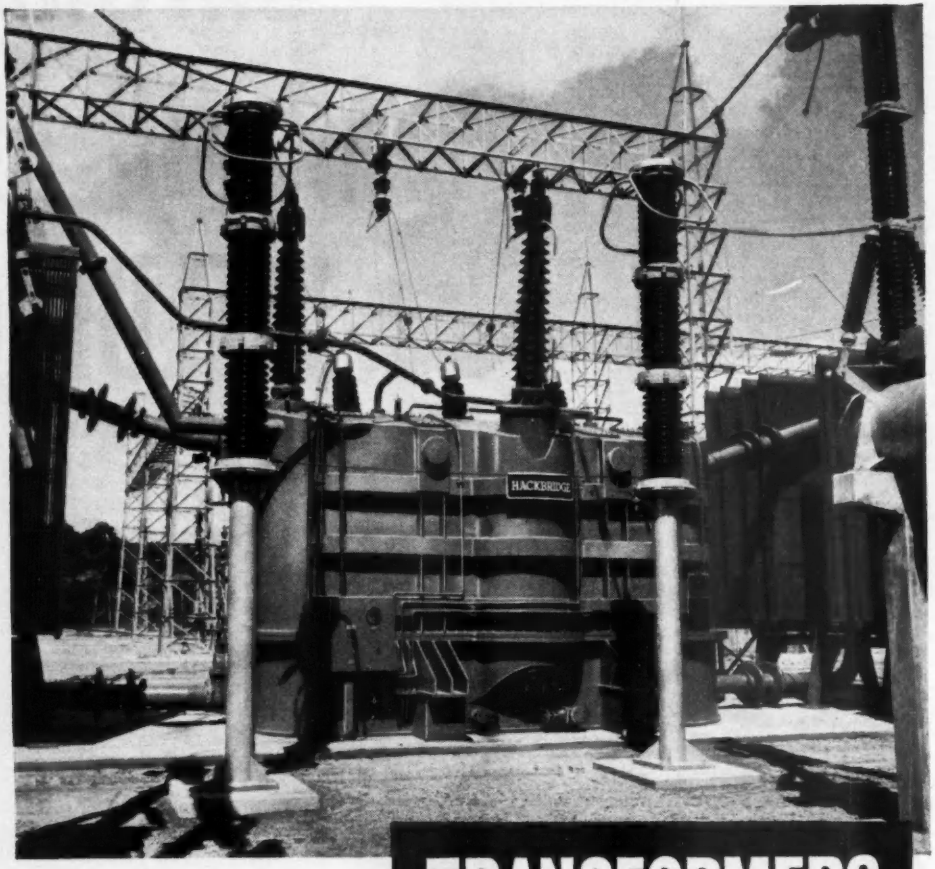

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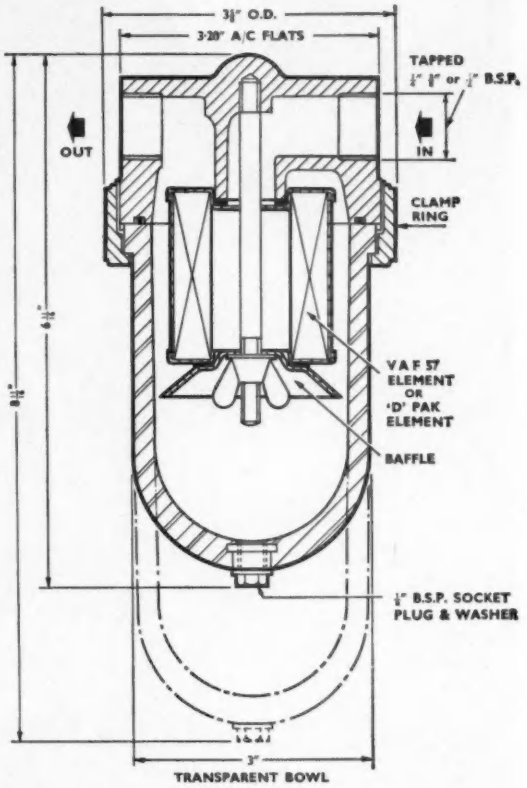

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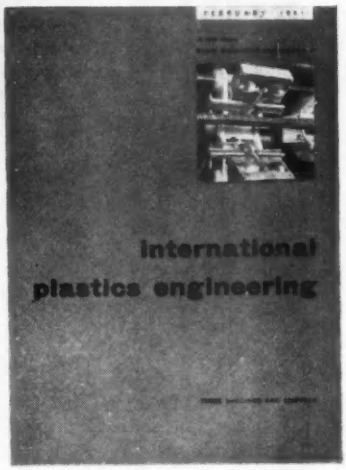

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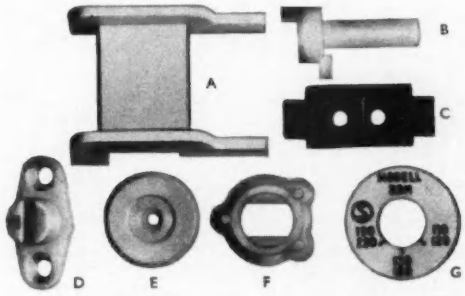

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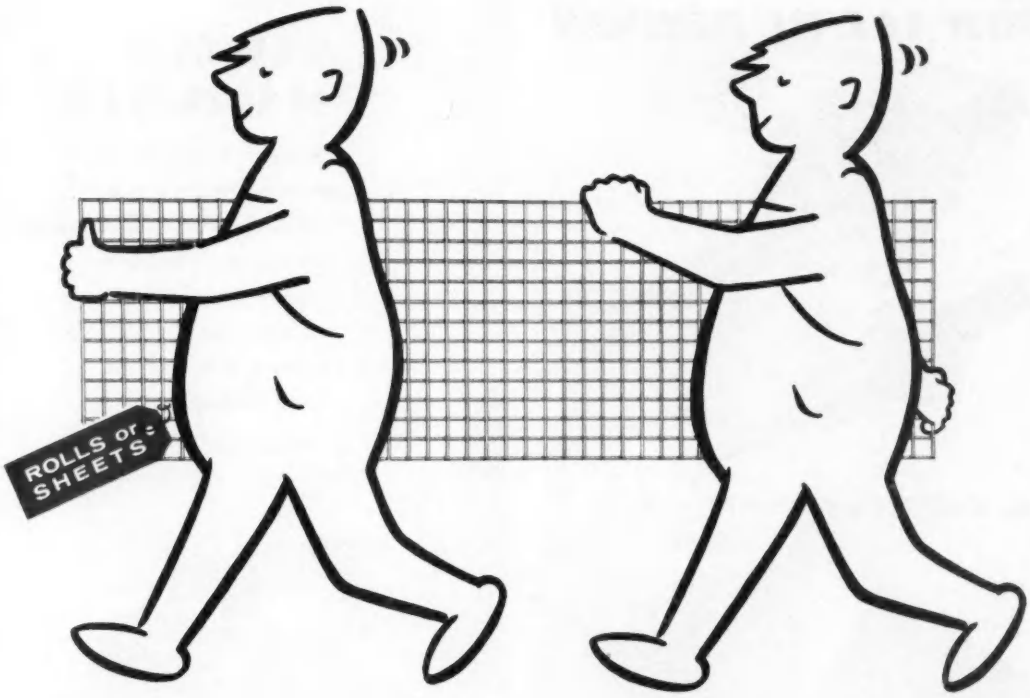

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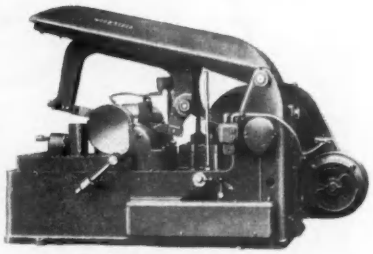

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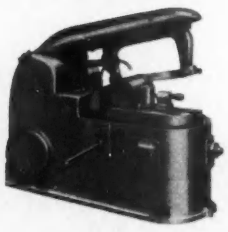

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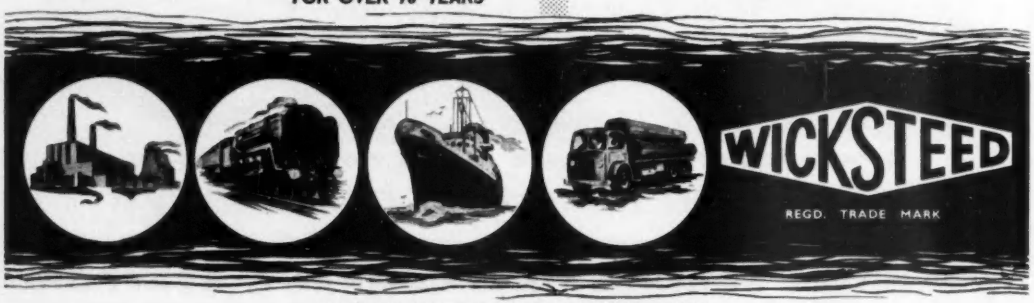

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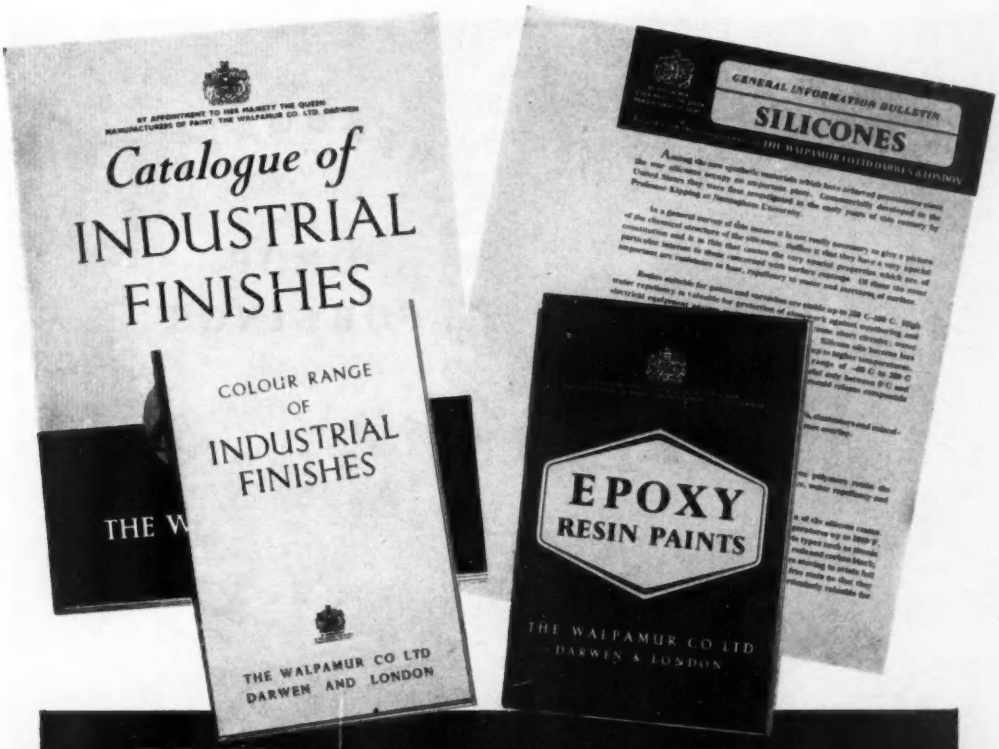

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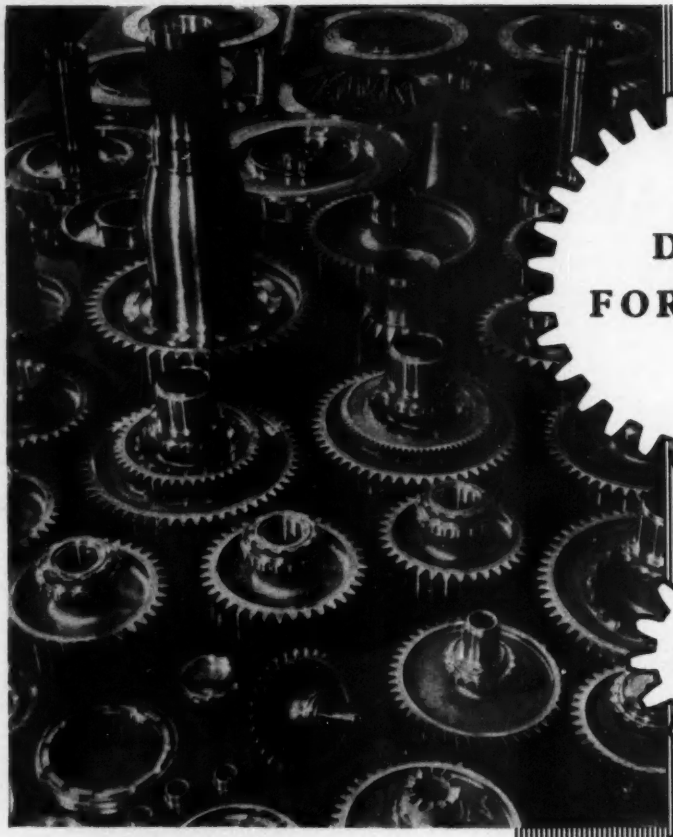

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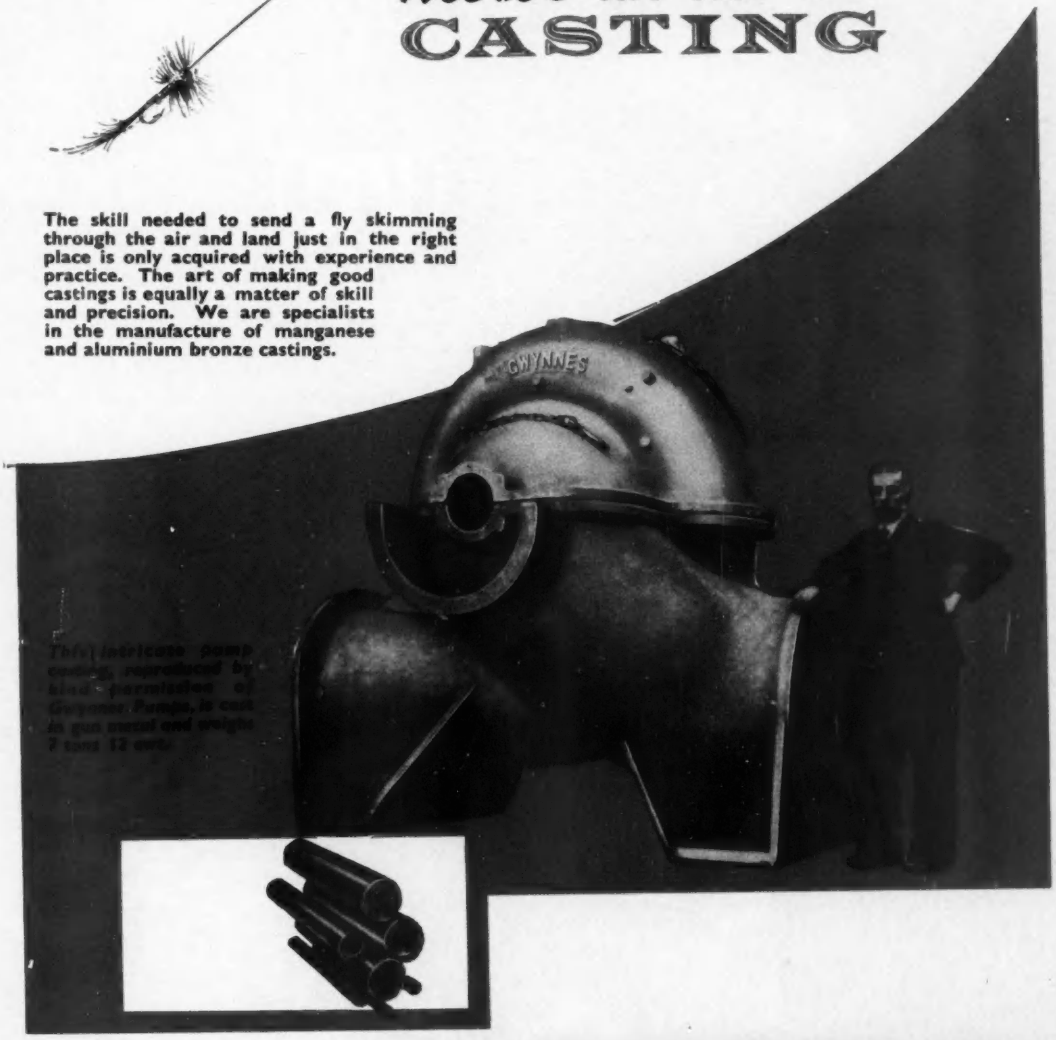

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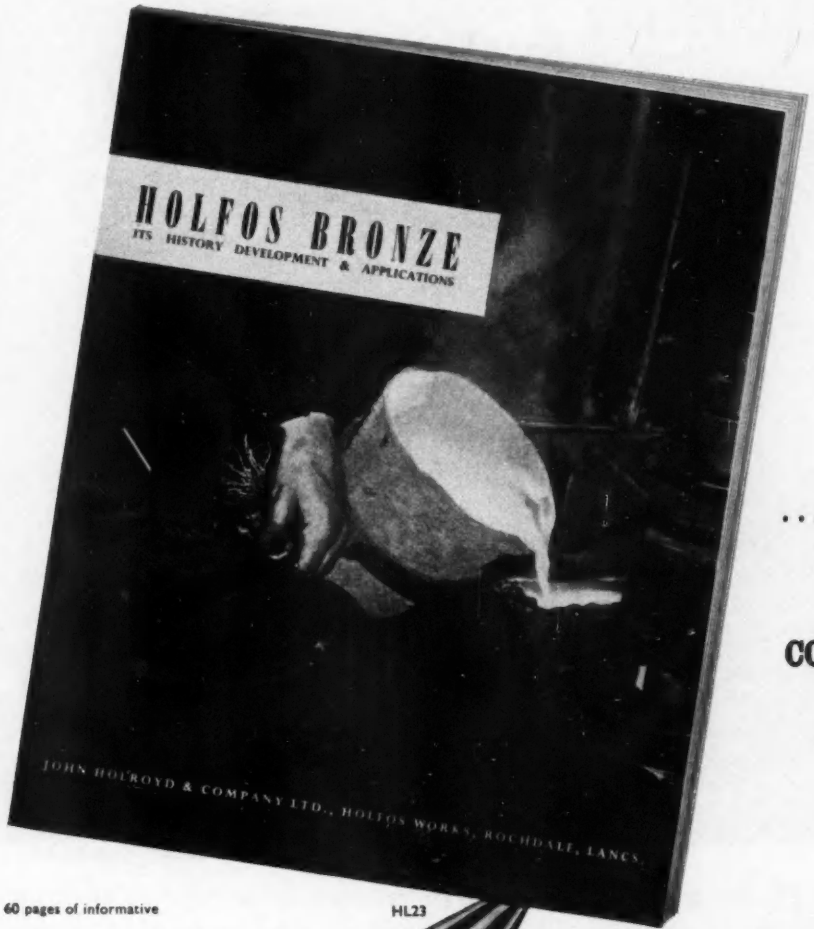

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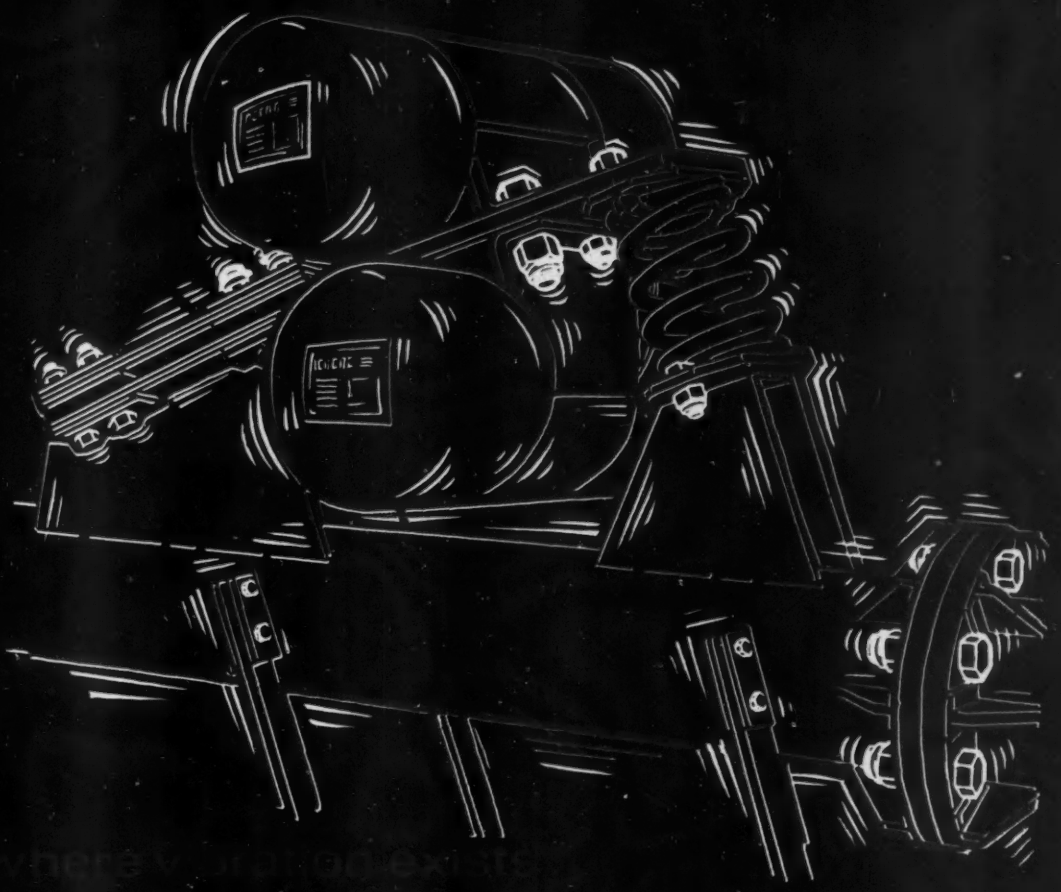

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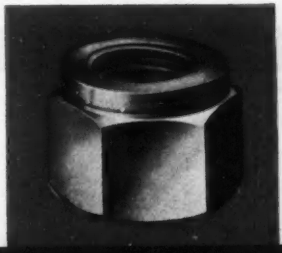

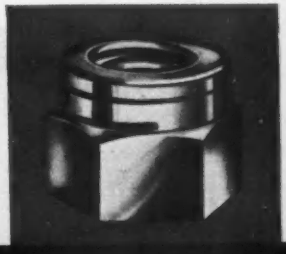

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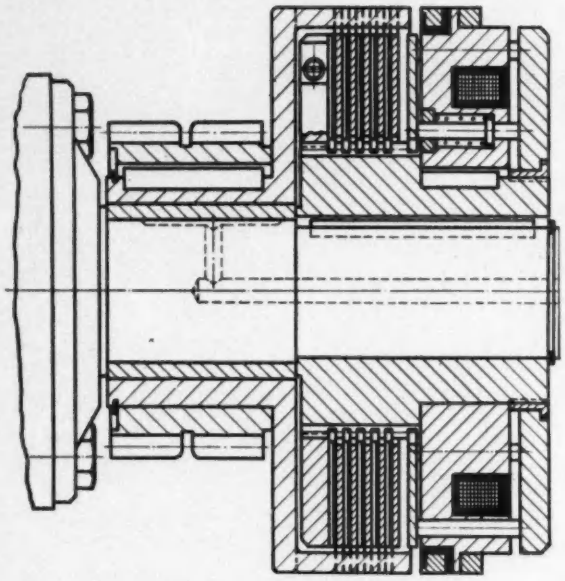

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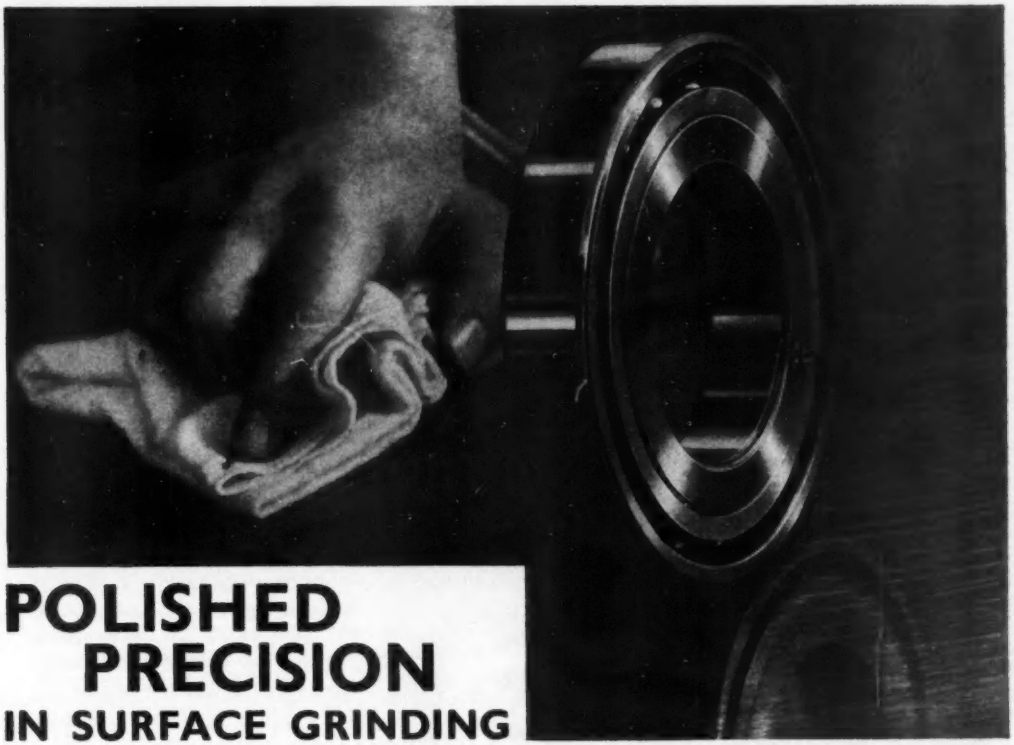

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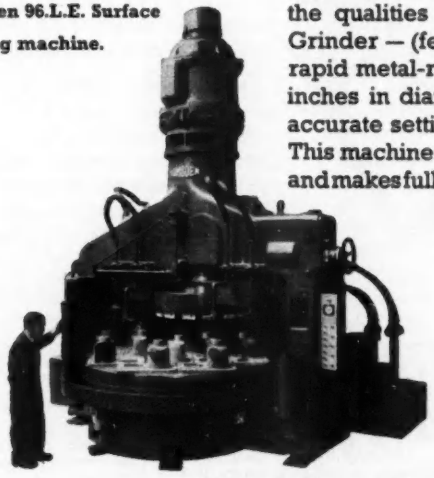
Lumsden 96.L.E. Surface grinding machine.



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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *IMPROVED DESIGN OF MAGNETRON OSCILLATOR*

Magnetrons with a non-split cylindrical anode, i.e., of the type where the anode is not subdivided into two or more segments, have long been considered unusable in practice, though they have recently gained importance as oscillators which can be electronically tuned. It should, however, be appreciated that, despite their admitted advantages, particularly with regard to their mechanical simplicity and the moderate magnetic field required, these oscillators have an inherent drawback in that the electronic current must be limited by means of the emission of the cathode in the saturated state. At present, use is made of cathodes of a pure metal, e.g., tungsten, the emission of which can be adjusted as a function of temperature. Quite apart from the rather low efficiency of such cathodes, they require, for the maintenance of the current at a fixed value, some means of automatic regulation which is not only complicated, but also of somewhat questionable effectiveness, especially in the case of magnetrons with an external electrode.

To overcome these drawbacks, an improved design of magnetron with a non-split anode has been patented, using a conventional oxide-coated cathode, if desired. The new magnetron contains two elementary structures, i.e., a cathode structure and an interaction structure, both structures being coaxial and mounted in the same magnetic field. The cathode structure is a magnetron-diode consisting of a cathode and an anode, the only purpose of this structure being to produce electrons which will pass into the interaction structure. The interaction structure is a magnetron which, in lieu of the cathode, contains a non-emissive electrode carried at a potential substantially the same as that of the cathode in the cathode structure. The non-emissive electrode and the cathode can be built in one piece, and can both be arranged either outside or inside their respective anodes, which can, in some cases, also be made in one piece. The shape of the two anodes and/or their potentials are chosen in such a way as to create an axial component of the electric field, capable of attracting electrons inside the interaction structure, in which the high-frequency energy exchange between the electrons and the high-frequency electric fields principally takes place.

From *Brit. Pat. Spec.* 855,568.
Compagnie Française Thomson-Houston, Paris.

● *SYNTHETIC MATERIALS REINFORCED WITH ALKALI-CONTAINING GLASS FIBRES*

Various synthetic resins, particularly phenol, melamine, urea, or unsaturated polyester resins, are often reinforced with glass fibres or mineral fibres to obtain products of greater tensile strength and elasticity. However, use is made in most cases of so-called alkali-free glass, i.e., compositions in which the total percentage of Na_2O and K_2O does not exceed 2%, in order to protect the resin against any alkali which may issue or migrate from the glass. In addition, such glass fibres are generally subjected to further treatment by applying intermediate layers which serve to increase the affinity or bonding of the fibres to the resin.

To overcome the difficulties inherent in processes using alkali-free glass, a recently patented process is designed to provide a synthetic resin reinforced with fibres of an alkali-containing glass or mineral, with an alkali content between 5 and 20%, and a coating of an epoxide resin. Essentially, the process involves the application of a hardenable compound or composition containing epoxy groups to the fibres before treatment with the synthetic resin. In this way, alkali cannot escape from the glass surfaces, as the intermediate layer of epoxy resin with which they are coated prevents separation or migration of any alkali. It is stated that considerable savings can be obtained, inasmuch as alkali-containing glass fibres are appreciably cheaper than alkali-free fibres. Furthermore, the hardenable compositions containing epoxy groups used in the process are well known and can be produced by simple methods.

Particularly good results are obtained with resin-like epoxy polyesters of high molecular weight, such as those obtained by the conversion

Readers desiring further information on any developments reported in THE BLUE PAGES are invited to write to the Editor. Copies of the full specifications of any British patents mentioned, which are published by courtesy of H.M. Stationery Office, should be obtained from the Patent Office, 25 Southampton Buildings, Chancery Lane, London, W.C.2. Price 3s. 6d. each.

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of alkali salts of aromatic dicarboxylic acids, e.g., phthalic acid, with epichlorhydrin. The amounts in which these epoxy compounds are applied to the fibres vary within wide limits, but at least 0·1% by weight, based on the weight of the fibres, is considered necessary to achieve a technically useful effect, with a maximum of less than 10%. The surface of the glass is capable of binding the epoxy compositions without the addition of hardeners or curing agents, but, in general, it is considered advantageous to use hardeners in amounts between 10 and 30% of the weight of the epoxy compound.

From *Brit. Pat. Spec.* No. 855,548.
Glaswerk Schuller G.m.b.H., Wertheim, Germany.

● *SPRAY-COATED PLATINUM RESISTORS FOR FURNACE HEATING ELEMENTS*

Platinum and platinum alloys are widely used as resistor materials for high-temperature electric furnaces, their high melting point and resistance to oxidation permitting much higher temperatures than are possible with the majority of conventional resistor materials. Because, however, platinum gradually volatilizes at high temperatures and because there is a tendency to slow crystal growth, with possible embrittlement and fracture of the metal. a new method of producing these electrodes has been specifically developed with a view to reducing or inhibiting these disadvantages.

The new method is based on the discovery that volatilization and a tendency to embrittlement can be reduced by applying to the platinum resistor a flame-sprayed coating of a refractory oxide, such as alumina or zirconia, the resistor being first provided with a fine knurled, scratched, or etched finish. It has also been discovered that excellent results can be obtained if the platinum resistor is first flame-sprayed with platinum or a platinum alloy to an average thickness of between 0·001 and 0·005 in., prior to applying the sprayed coating of refractory oxide. The sprayed platinum bonds firmly to the previously roughened resistor metal and provides an ideal surface for the subsequent oxide coating, as the sprayed platinum has a high degree of surface roughness and many deep depressions and re-entrant angles. This interlayer of sprayed platinum also appears to help reduce stresses on the oxide coating, caused by the considerable difference in the coefficients of expansion of platinum and alumina or zirconia.

It should also be noted that the flame-sprayed coating of platinum, when used alone on the surface of the resistor, is effective in reducing to a considerable extent the rate of volatilization. Also, for reasons which as yet cannot be explained, it appears to inhibit excessive crystal growth on the surface of the resistor. Thus, for instance, under identical test conditions, an untreated platinum resistor showed a 12½% loss by volatilization and pronounced crystal development, whereas a platinum-sprayed specimen showed a loss of only 7% by volatilization and no apparent crystal development, and a sample which had been both platinum-sprayed and alumina-coated showed no loss at all.

From *Brit. Pat. Spec.* 856,309.
Norton Grinding Wheel Company Limited, England.

● *INVESTIGATION INTO THE FLAME-SPRAYING OF ALUMINA ON METALS*

Of the three methods currently available for applying coatings to metal by particle impact, i.e., flame-spraying, detonation, and plasma jet, the flame-spraying technique offers the advantages of mobility and relative ease of operation. However, although the coating of parts by flame-spraying has been practiced for many years, the application of alumina by this means is a relatively new development.

Experiments have shown that the strength of the bond formed between alumina and iron increases exponentially with an increase in the surface roughness of the substrate. In order to measure bond strengths, metal strips, roughened to various degrees by different blasting treatments, were spray-coated with alumina to a thickness of 0·010 ±0·002 in., and the force required to shear the coating from the strip was then determined. It was found that sprayed particles of alumina did not adhere to metal strips which had been polished, while the measured bond strengths for surfaces which had undergone severe roughening were many times greater than those for surfaces which had received only a mild roughening. Also, the bond strengths of coatings formed with a rod gun were higher than they were for those coated with a powder gun.

The thermal properties of a material influence the flow of molten particles immediately following impact. Thus, when a particle strikes glass, it cools less rapidly than when it strikes metal, allowing more time for a chemical bond to form. The initial cooling rate of molten alumina from 2050 to 1800°C on glass was computed to be 34,000°C/sec, as against 800,000°C/sec on stainless steel and, to indicate whether slower cooling would also give a chemical bond with metal, thereby augmenting the mechanical bond, tests were carried out with a strip of iron coated with porcelain enamel, which was in turn covered with a 0·0003-in. layer of nickel. It was found that the ceramic substrate effectively lowered the cooling rate of the sprayed particles, but bonding was not improved. Good bonding was obtained on glass, irrespective of whether the surface was rough or smooth, whereas on iron the bond

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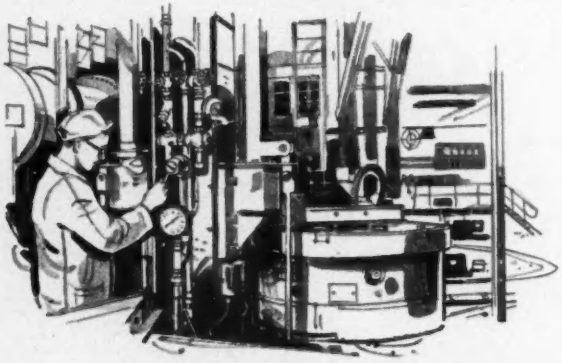

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strength, as mentioned, was substantially increased by roughening the surface. These results suggest that the bond between the alumina coating and a glass substrate is largely chemical, whereas that formed between flame-sprayed alumina and metals is mainly mechanical in nature.

From *NBS Technical News Bulletin*, U.S.A., December 1960, pp. 202-203.

● *SHEET-METAL SPARK-IGNITION PETROL ENGINE*

A remarkable new spark-ignition petrol engine incorporates a cylinder-block made of sheet-metal stampings and has a power-to-weight ratio of 1 hp/lb, a recently displayed water-cooled four-cylinder engine of this type being capable of developing 175 hp and weighing 175 lb. A brazed assembly of stainless-steel stampings, comprising cylinders and cylinder heads, water jacket, intake and exhaust ports, upper block pan, and spark-plug tubes, forms the lightweight upper block. The stampings are first tack-welded to retain alignment, and are pressed as a unit into a cast-steel hold-down flange. The entire block is then brazed in a hydrogen atmosphere in a gas or electric oven at 2100°F. Each part is so designed that heating and cooling produce virtually no measureable distortion, despite the different coefficients of thermal expansion.

The engine is available in four displacement sizes, ranging from 91 to 135 cu in., with respective power ratings from 115 to 175 hp, and can be converted from one size to another simply by replacing the crankshaft to change the stroke. All sizes develop maximum power at 6500 rpm, respond to performance improvement by the use of turbocharging, and have a compression ratio of 12 : 1, a ratio of 14 : 1 being optional. Because the stainless-steel sheet employed to form the various block components can be held to a uniform wall thickness, the engine cools evenly without hot-spots. The thin-gauge metal (0·09 in.) used for the combustion chamber and the ports also dissipates heat several times faster than a cast block. A 0·063-in. liner is brazed into each cylinder to ensure low wear and long engine life.

From *Machine Design*, U.S.A., November 10, 1960, pp. 6 and 8.

● *NICKEL-ALUMINIUM COATINGS FOR HIGH-TEMPERATURE PROTECTION OF METALS*

According to a recent report, two new methods have been developed for producing nickel-aluminium coatings for the protection of metal sufaces at temperatures up to 1830°F. These coatings, which have already proved effective on steel, nickel, and molybdenum and which will probably be applicable to other metals, are expected, because of their high oxidation resistance, to prove useful for many aero-space applications.

In the first and more satisfactory method, nickel is deposited from a Watts-type bath. Aluminium is then deposited on the nickel layer at a current density of 19 to 139 A/sq ft from a fused-salt solution, containing a mixture of potassium chloride, sodium chloride, and cryolite, at 1290°F. At this temperature, the aluminium diffuses into the nickel layer as it deposits, thus forming the alloy. The second method, suitable for plating aluminium, has been specifically developed for parts that cannot withstand the high temperatures necessary to operate the cryolite bath. In this method aluminium is deposited over the nickel layer at 320°F from a fused-salt bath consisting of aluminium chloride and sodum chloride. The coating is then alloyed with the nickel by heating for a few hours in air at from 930 to 1110°F.

Steel specimens coated with nickel-aluminium alloy have been tested under various conditions in air at elevated temperatures, in salt spray, and outdoors. In air at 1020°F and 1830°F, the coatings oxidized at one-tenth of the rate of nickel coatings of comparable thickness. Panels plated from the cryolite bath had better resistance to salt spray. Thus, panels coated with 0·002 in. of nickel and 0·0005 in. of aluminium have withstood 300 hr in salt-spray tests before showing rust. Also, thermal cycling of these panels between room temperature and 1020°F did not affect their corrosion resistance.

From *Materials in Design Engineering*, U.S.A., November 1960, p. 10.

● *COBALT OXIDES AS CATALYSTS FOR THE COMBUSTION OF EXHAUST GASES*

Among the techniques that can be considered feasible for the purification of the exhaust gases of petrol engines, the catalytic oxidation of their noxious constituents, i.e., hydrocarbons and carbon monoxide, by secondary air appears to be of special interest because of the simplicity of its application. However, to be suitable for use in an afterburner, catalysts must be capable of withstanding the severe conditions to which they will be subjected in operation. In addition to possessing adequate resistance to attrition and to poisoning by lead compounds, they must possess a high activity at relatively low temperature, in order to be able to initiate catalytic combustion when the exhaust gases are at their lowest temperature, e.g., when the engine is idling. On the other hand, they must retain their high activity when exposed to elevated temperatures for prolonged periods, e.g., when the engine is fully loaded.

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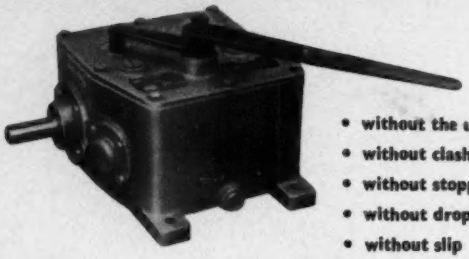

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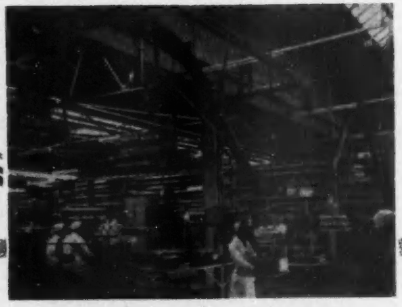

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prospects as active materials for catalytic afterburners, and a recent paper describes experiments carried out with a view to determining the various factors which influence the useful life of these catalytic materials. Long-duration tests carried out on unsupported cobalt oxides, as well as on cobalt oxides supported by calcium aluminate, gave very promising results as far as conversion efficiency, ignition power, and resistance to lead poisoning are concerned. In the present stage of development, a useful life of at least 1000 hours can be expected from these materials, but further investigations should lead to improvements, the main effort being directed towards increasing their surface area and stabilizing it at high temperatures, and improving their ability to start conversion at low temperatures.

From *Cobalt*, Belgium, December 1960, pp. 12-21.

● ***HOT-EXTRUSION PROCESS FOR SMALL SECTIONS***

Present-day methods of hot extrusion cannot be employed for the extrusion of very small sections. The smaller the section of the extruded bar, the greater is the elongation of the billet, and the higher must be the specific pressure applied to the billet in order to produce its deformation, so that, for a press of a given capacity, the maximum available specific pressure is the quotient of the effort applied by the press and the cross-section of the container. In consequence, it becomes necessary to reduce the diameter of the container in order to obtain a higher specific pressure. However, there is also a limitation in this respect, depending on the stresses which the tools are capable of withstanding, so that, for a given press and for a given metal and tooling, there exists a maximum value of product section obtainable by extrusion.

These drawbacks are claimed to have been overcome by a new method of hot extrusion, which is based on the discovery that, by placing bars or tubes concentrically into a casing of a metal which can be more easily extruded than the bars or tubes, and extruding the assembly thus formed, it is possible to obtain a product in bar or tubular form of very small section. In the case of tubular products, very small wall thicknesses can be produced in this way. In order to prevent adhesion of the individual bars or tubes during the extrusion process, they can be subjected to a surface-oxidation treatment, or can be covered with vitreous lubricants, e.g., a paste of sodium silicate and alumina. To give an example of the potentialities of this method, a mild-steel casing of 110 mm internal diameter was filled with 110 rods of 18-8 stainless steel, 9 mm in diameter and 250 mm in length. This assembly was then extruded, using vitreous lubricants into a round "rod" of 9-mm diameter, with the result that the encased rods were transformed into wire having a section equivalent to round wire of 0·8 mm diameter and a length of 3·6 metres. The sheath could easily be removed by slitting, and the wires readily separated from each other.

From *Brit. Pat. Spec.* 855,876.
Comptoir Industriel d'Étirage et Profilage de Métaux, Paris.

● ***SOLID ROTORS FOR INDUCTION MOTORS WITH COPPER-IRON SURFACE LAYERS***

In induction motors with solid rotors wholly composed of iron, the magnetic screening effect of eddy-currents induced in the rotor serves to concentrate the currents over a thin surface layer of the core. The heating effects produced by these currents are effectively confined to this layer, so that, in certain applications, the heating effect of the rotor tends to limit the design rating of a motor of given size to a value determined by the thickness of this conducting layer. In the case of solid iron rotors with copper surface layers, the magnetic skin thickness is considerably greater, owing to the reduced permeability of the surface layer. However, despite the rapid distribution of the heating effect over the layer and a reduction in this effect for a given torque, the stator-field magnetic circuit has a high reluctance, detracting from the performance of the motor.

It has now been found that, by using for the surface layer of the rotor a material which does not have the very low permeability of the non-magnetic copper or the relatively very high permeability of the iron, a desirable compromise can be achieved. It is for this reason that a recently patented process is concerned with the provision on the rotor of a macroscopically homogeneous surface layer of a mixture containing iron and at least 60% copper. The layer can be applied by any suitable means, such as electrolytic plating, sintering, or spraying, the latter being the preferred technique. In practice, two spray guns are used simultaneously, one applying the copper and the other the iron to the surface of the rotor, the metal used being in the form of soft drawn wire fed at a controlled rate and temperature through the guns. To avoid brittleness and consequent cracking, the copper content is, as already stated, at least 60%, rendering the surface layer more ductile, and the rotor is cooled by passing air through its interior during application of the spray. In a typical application, a suitable requirement is a surface layer having a thickness of 0·03 in. and a magnetic permeability of 30, for which purpose the sprayed surface of the rotor contains about 75% copper and 25% iron.

From *Brit. Pat. Spec.* 857,071
The English Electric Co. Ltd., London.

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A World Review of DESIGN & PRODUCTION — RESEARCH & DEVELOPMENT

VOL. XXII No. 2 FEBRUARY, 1961

High-Velocity Impact Tests with Bullets

By A. BARTOCCI

From *La Metallurgia Italiana*, Italy,
Vol. 52, No. 9, September 1960,
pp. 587-600, 9 illustrations.

IN order to obtain indications of the dynamic strength of metals at high loading rates, the investigation described in this paper is concerned with specimens subjected to rupture tests by means of bullets fired from a gun. With violent tests of this type, it was not expected that more than exploratory assessments could be obtained. However, the scarcity of results in this field was considered an encouragement to try out this method, as the results obtained might well be of practical interest.

Notched bars of the Mesnager type were used as impact-test specimens, the bars being hit by the bullets on the side opposite to the notch. Fired from a smooth-bore gun of 12·7 mm calibre, the bullets used were hard-steel bearing balls with a mean diameter of 11·9 mm and a mean weight of 8·5 grams, provided with a lead jacket which was cast off during flight. The required velocities at impact (260 to 270 m/sec and 415 to 425 m/sec) were obtained by adjustment of the propellant charge. During testing, modifications were made to the procedure adopted and also to the shape of the specimens, with a view to finding the optimum test conditions.

Preliminary Tests

Preliminary tests were conducted for the purpose of determining the residual energy of the bullet after impact and also the energy absorbed in the impact from the dimensions of the impression produced in the specimen. This energy was then compared with values of impact strength obtained by means of a Charpy pendulum of 30 mkg, which was provided with a steel ball of the same diameter as that of the bullets, instead of the usual striker.

In these preliminary tests, an annealed copper plate was used as a target, the impact velocities of the steel ball ranging from 230 down to 115 m/sec. Lower velocities could not be used because of the risk that the bullet might not be ejected from the gun barrel and also because, with the more pronounced curvature of the trajectory at lower velocities, it would have been difficult to measure the impression on the copper plate with sufficient accuracy. Fig. 1 shows a curve of the measured diameter of the impressions produced as a function of the impact energy of the bullet, as calculated from its impact velocity, and indicates the actual test results (solid circles).

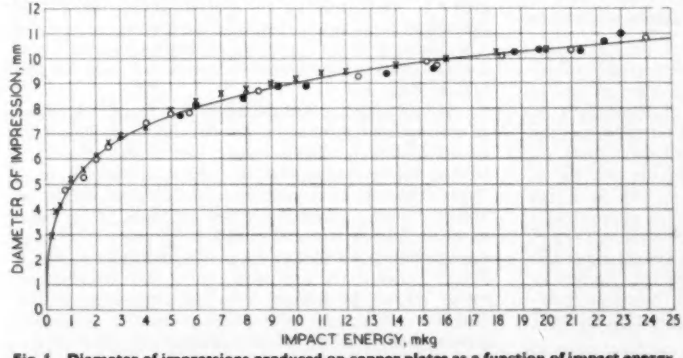

Fig. 1. Diameter of impressions produced on copper plates as a function of impact energy, test points with high-velocity bullets being indicated by solid circles, and Castiello hammer tests by open circles for a 15-kg weight, and by crosses for a 10-kg weight.

A correlation of these results with those obtained by standard tests was attempted, using a Castiello hammer provided with a steel bearing ball identical with those used in the bullet tests, i.e., of 11·9 mm diameter. These hammer tests were carried out with falling weights of 10 and 15 kg at different heights to give impact energies in the same range as those in the bullet tests. Despite the great differences in impact velocity, good agreement with the previous tests was obtained, as shown in Fig. 1. The two sets of results are of particular interest, because they confirm Castiello's finding that the diameter of the impression depends on impact energy and not on impact velocity for masses ranging from a few grams to 10 or 15 kg, which is a very much wider range of variation than that actually investigated by Castiello.

Additional hammer tests were then made on steel specimens, under the assumption that, for these specimens, the diameter of the impression also depends on impact energy and not on impact velocity. Specimens of various Brinell hardnesses (223 to 578) were prepared from a 40-mm diameter bar of a chrome-nickel-molybdenum steel. Castiello hammer tests, using the steel ball and impact energies of 20 and 25 mkg, were carried out to determine the relationship between hardness values and the diameter of the impression produced, and the results are given in Fig. 2. Bearing in mind that, in Fig. 1, the curve is virtually linear in the range between 20 and 25 mkg, Fig. 2 can be redrawn to give the relationship between the diameter of the impression and impact energy for different hardness values (Fig. 3). Also, although the results in Fig. 3 are based on the Castiello hammer test with low impact velocities, it

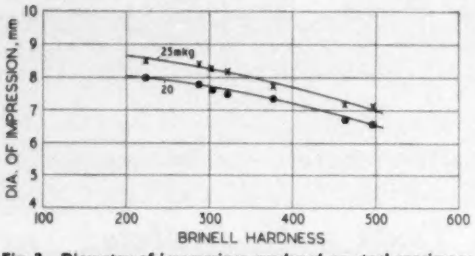

Fig. 2. Diameter of impressions produced on steel specimens with a ball-ended Castiello hammer with impact energies of 20 and 25 mkg, as a function of Brinell hardness.

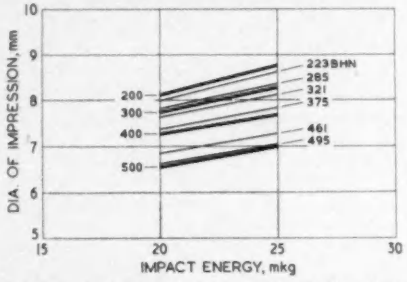

Fig. 3. Diameter of impressions produced on steel specimens as a function of impact energy, for various Brinell hardnesses, based on the results given in Fig. 2.

would appear from Fig. 1 that they are also valid for high-velocity impacts.

Because, in bullet impact tests, rupture of the specimen is obtained with a steel ball instead of with a striker, as in the standard Charpy test, it was decided to carry out additional comparative experiments with a Charpy pendulum of 30 mkg, which was provided first with a striker and then with a steel ball of 11·9 mm diameter, i.e., of the same type and size as the steel bullets. Close agreement between these two types of Charpy tests was obtained. Various types of alloyed and unalloyed steels of different hardnesses were tested, and it was found that the diameter of the impression in the specimen (which could be measured with considerable accuracy in these pendulum tests) was not strictly related to the hardness of the steel but also depended on the impact strength [mkg/cm^2]. This finding may be worth further examination in a future programme.

High-Velocity Rupture Tests on Simply Supported Bars

Tests were carried out on simply supported notched-bar impact specimens, with bullet velocities of 260 to 270 m/sec and 415 to 425 m/sec, corresponding to impact energies of 30 and 75 mkg. After rupturing the specimen, the spherical bullet struck a copper plate, on which it produced an impression. From the diameter of this impression and the curve given in Fig. 1, it was possible to determine the residual energy after impact; this energy was then subtracted from the initial energy of the bullet, in order to obtain the total energy expended in the rupture of the specimen. This energy, divided by the initial rupture cross-section of the Mesnager specimen, was regarded as the high-velocity impact strength K_V of the specimen.

This K_V-value obviously is only an indicative quantity, since it is far from the value of energy per unit area effectively required for rupture of the specimen. There are various other factors in the test which cause absorption of energy, i.e., the impression produced by the bullet in the middle section of the specimen, the violent separation of the two halves of the test bar (this energy loss is considerable, since it occurs at high velocity), the impression produced on the two halves by the supports, and other factors more or less easy to define, depending on the violence of the test. Moreover, the value of impact strength is affected by additional factors, such as the angle of incidence of the bullet when striking the copper plate (possibly producing a smaller impression), the deformation and reduction of the cross-sectional area of the specimen before rupture, etc.

After these tests, the two fractured portions of the bar were joined together, and the angle of rupture was measured, as well as the mean diameter of the impression made by the bullet on the bar.

The results of the impact tests with bullet velocities of 260 to 270 m/sec on steel specimens of the types used in the preliminary tests, and the corresponding results of Mesnager tests with a 30-mkg pendulum and a steel ball, are shown in Fig. 4. Each bullet impact test was carried out on three specimens, and the scatter of the test results (indicated by solid circles and by open circles in the case of tests with an appreciably deflected bullet) was less than expected for violent impacts of this type. The residual energy transferred to the copper plate was low (not exceeding 3·25 mkg in any of the tests); it therefore appears that nearly all the energy available was absorbed in the rupture of the specimens.

One of the specimens, with a Brinell hardness of 302, was not ruptured by the bullet. The specimens with maximum hardness (578 Brinell) did not rupture regularly but broke up into several pieces, with an angle of rupture of between 175 and 180 deg. The angle of rupture decreased with decreasing hardness, reaching 150 deg. for the specimens with a Brinell hardness of 223.

The curve for the Mesnager tests in Fig. 4 shows a minimum value of impact strength at a Brinell hardness of about 400 and this minimum is certainly related to temper brittleness. The curve for the bullet tests is fairly flat and shows a rising tendency only towards the lower values of hardness, with only a slight variation indicating temper brittleness.

The dotted curve in Fig. 4 is obtained by shifting the curve (2) upwards in order to relate the impact energy to the reduced cross-section after deformation, instead of to the initial cross-section of the specimen. The dotted curve is given only as an approximation, since it is difficult to measure the reduced cross-sections accurately. The diameter of the impression varied from about 7 mm for the hardest specimens to about 8·5 mm for the softest specimens.

An approximate estimation of the energy absorbed in making the impression in the bar can be attempted by means of Fig. 2. For example, one of the specimens, with a Brinell hardness of 461, had an impression of 7-mm diameter, corresponding to an absorbed energy of about 21·7 mkg, whereas another specimen, of the same hardness, had an impression with a diameter of 7·5 mm, corresponding to about 27 mkg. The difference of about 5 mkg between the two tests shows that deformation energy cannot be defined from the impression in the specimen. It is, however, a high proportion (certainly greater than 50%) of the total energy absorbed by the specimen in high-velocity impact tests. Consequently, for practical purposes, it is preferable to quote the

overall energy absorbed by the specimen, instead of the energy required for rupture.

The second series of tests, with bullet velocities of 415 to 425 m/sec, was carried out on specimens of a chrome-silicon-manganese steel. The specimens, taken from a forged steel bar of 40-mm diameter, were reheated to various tempering temperatures in order to obtain a wide range of hardness values and Mesnager impact strengths. The results of the bullet impact tests at 420 m/sec (with a bullet impact energy of 75 mkg) and of the Mesnager tests with a ball-ended Charpy pendulum of 30 mkg, are shown in Fig. 5.

The curve for the bullet tests again shows very little variation in absorbed energy, despite the range of hardness values investigated. In all these tests, the residual energy did not exceed 8·6 mkg; thus, even more so than in the previous tests, practically all the available energy was absorbed in the rupture of the specimen. The test points of the high-velocity impact tests in Fig. 5 show considerable scatter. The broad band of values thus obtained does not indicate the trend indicated by the Mesnager tests on specimens of the same types. The dotted curve (with values referred to the effective rupture cross-section) is even more uncertain. Finally, some explanation is needed for the fact that specimens with a Mesnager impact strength of about 2 mkg/cm² attain a high-velocity impact strength of about 100 mkg/cm².

Further tests were carried out on a variety of other materials. Thus, for example, a rolled steel, with a U.T.S. of 43 kg/mm², was found to have a Mesnager impact strength of 12 mkg/cm² (as determined with a ball-ended Charpy pendulum) and a high-velocity impact strength of more than 37·5 mkg/cm² at 265 m/sec. A wrought iron, with a U.T.S. of 28 kg/mm², had a Mesnager impact strength of 1·5 mkg/cm², as compared with a high-velocity impact strength of 79·2

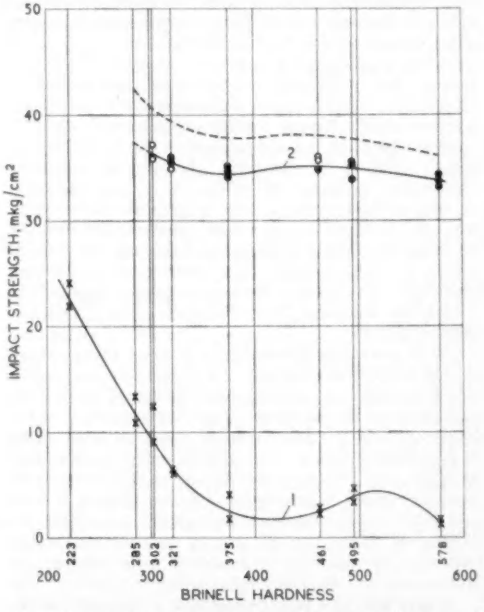

Fig. 4. Impact strength as a function of the Brinell hardness of steel specimens, as obtained (1) by Mesnager tests, and (2) by bullet tests at 265 m/sec.

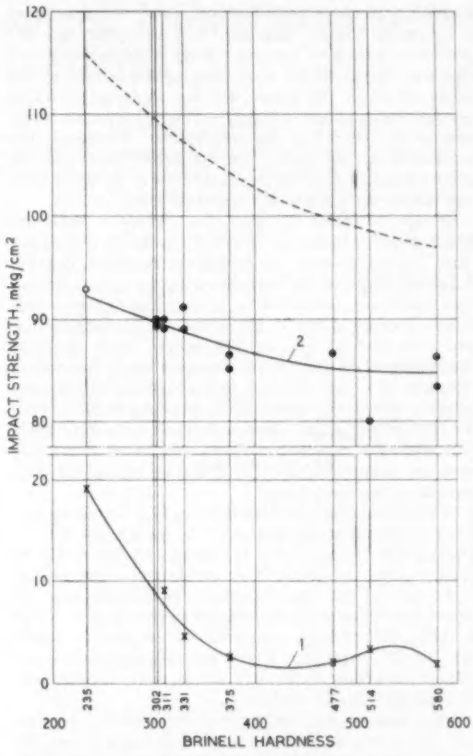

Fig. 5. Impact strength as a function of the Brinell hardness of steel specimens, as obtained (1) by Mesnager tests, and (2) by bullet tests at 420 m/sec.

mkg/cm² at 420 m/sec, while a copper specimen had a Mesnager impact strength of 6·2 mkg/cm² and a high-velocity impact strength of 85·5 mkg/cm² at 420 m/sec. On the other hand, a duralumin specimen had a Mesnager impact strength of just over 1 mkg/cm² and a high-velocity impact strength of only 55 mkg/cm² approximately at 420 m/sec. These results deserve careful examination, as they may yield interesting conclusions. In particular, the exceptionally low value of high-velocity impact strength recorded for the duralumin specimen is worth noting.

High-Velocity Rupture Tests on Cantilever Specimens

For high-velocity rupture tests on cantilever specimens, notched test-bars of the true Mesnager type were made, with the exception that one end was enlarged to a square section with sides of 20 mm and a thickness of 10 mm. This end was left free, the other end being clamped in a vice. In a preliminary series of tests, this square-section head was provided with a cover-plate of hard steel, 10 mm thick, designed in such a way that it could be fitted over the head of the specimen, the bullet striking this plate at the centre of the square section of the specimen.

With this arrangement, it was hoped to obtain ruptured sections which would be unaffected by the impression of the bullet, and also impressions on the cover-plate which could be measured with sufficient

accuracy. In these tests, however, even with specimens of moderate impact strength, it was found that the specimens were bent but not ruptured, while the cover-plate was ripped off the supporting square section by the bullet, which at the same time was deflected upwards through angles of up to 20 deg., owing to the much larger mass of the head and the cover-plate. Moreover, the impression of the bullet on the cover-plate had ill-defined edges, so that the measurements of diameter were even less accurate than they were previously.

A second series of tests was therefore made on square-ended cantilever specimens without the cover-plate. In these tests, the specimens ruptured, but the ill-defined edges of the impression in the square section were again unsuitable for accurate measurements with bullet velocities of 415 to 425 m/sec. It is probable that with velocities of 260 to 270 m/sec, more accurate measurements of impression diameter could have been obtained, but the reduced impact energy might not perhaps have been sufficient to produce rupture with this type of specimen. Although fewer tests were made than with the simply supported specimens previously used, the results obtained nevertheless seemed to confirm the previous findings.

A third series of tests was then carried out on square-ended cantilever steel specimens. In these tests, the vice gripping the clamped end of the bar section could be rotated to any prescribed position about an axis parallel to the face of the square section, so that the angle of impact between the bullet and the square section could be varied. In this way, with a number of identical specimens set up at different angles but subjected to impacts with the same bullet velocity, it was possible to determine the limiting angle of rupture.

This limiting angle of rupture was used to calculate the relative impact energy, which was regarded as the total energy expended in the rupture of the specimen. It was therefore no longer necessary to measure residual energies from impressions on copper plates, as mentioned previously, and at the critical angle of rupture no additional loss of energy resulting from the violent separation of the sections of the bar needed to be taken into account.

This arrangement was found satisfactory, though in nearly all cases there was a slight twist of the ruptured bar because the point of impact of the bullet did not usually lie exactly on the vertical centre-line of the specimen. Thus, rupture was not due to pure bending only but included a torsional deformation. In these tests with oblique impact, the impression in the specimen was no longer a spherical segment but an oblong groove, and no attempt was therefore made to measure its dimensions.

Typical of the results obtained in this third test series are those noted for a 0·11% carbon steel, for which the Mesnager impact strength K was 14·14 mkg/cm², while the high-velocity impact strength K_V was about 37 mkg/cm² at 265 m/sec and 50 mkg/cm² at 420 m/sec, with a limiting angle of rupture α at 420 m/sec of 57·5 deg. Similarly, in the case of a 0·46% carbon steel, the value of K was 6·63 mkg/cm², with a K_V-value of 27 mkg/cm² at 265 m/sec and 35 mkg/cm² at 420 m/sec, with $\alpha = 72{\cdot}5$ deg. at 420 m/sec. The values, in the case of a chrome-nickel-vanadium steel, were $K = 17{\cdot}67$ mkg/cm², with $K_V = 37$ mkg/cm² at 265 m/sec, and 56·8 mkg/cm² at 420 m/sec, with $\alpha = 49{\cdot}5$ deg. at 420 m/sec.

This method gives sufficiently accurate measurements of high-velocity impact strength, because the limiting angle of rupture is well defined, and also because less energy seems to be dissipated by secondary factors in oblique impacts. These oblique-impact tests confirm the previous findings that the high-velocity impact-strength values at 420 m/sec are higher than those at 265 m/sec, and that both are much higher than the corresponding values of impact strength on Mesnager specimens, using a Charpy ball-ended pendulum and similar impact energies.

Theoretical Considerations

In an attempt to interpret the test results given above, it is useful to recall the laws governing impact phenomena which, for simplicity, assume an infinitely short impact with no vibrations. If m_1 and m_2 are the masses, and v_1 and v_2 their respective velocities (with $v_2 = 0$), the energy E_p dissipated by permanent plastic deformations during impact is

$$E_p = \tfrac{1}{2}(1-K^2)\, mv_1^2$$

where $m = m_1m_2/(m_1 + m_2)$ and k is the impact coefficient (equal to unity for perfectly elastic bodies). The impact energy converted into elastic strain energy E_e, reappearing as kinetic energy at the end of impact, is

$$E_e = \tfrac{1}{2}K^2mv_1^2$$

There are different expressions for E_p and E_e which would enable the shape of the simply supported test bar to be taken into account, but the above expressions are sufficient for qualitative assessments and show that the total energy E expended in the impact (and determining the K_V-values of the tests) is $E_p + E_e$, which increases with impact velocity, as shown in the results. However, the ranges within which these expressions apply are not defined. Impact energy is transformed first into elastic strain energy up to the elastic limit; when this is exceeded, energy is dissipated by plastic deformation up to a limit where rupture of the material occurs.

When a specimen is subjected to impact, it reacts against load application with a "static" reaction which depends on its material characteristics, and a "dynamic" reaction which depends on the intertia with which it opposes the shock wave passing through it. When the impact velocity is increased, the intertia opposing impact also increases and raises the energy-absorption capacity of the specimen. It is then reasonable to expect that the dynamic reaction will predominate over the static reaction at high velocities, so that the total energy values will tend to become the same, even for different materials. This agrees with the increasing flatness of the K_V-curves obtained from the tests with increasing impact velocity.

If the static reaction decreases in relative importance at high impact velocities and the diameter of the impression in the specimen is not greatly affected by velocity (as was observed in the tests), it can be inferred that the energy E_p required for plastic deformation and rupture of the testpiece does not vary greatly. This is equivalent to saying that the expression for E_p is valid only if the impact does not cause rupture. These points were fully confirmed by dynamic tensile rupture tests made by Mann, who found that the energy required for rupture remains unchanged up to a critical value of velocity, beyond which it decreases appreciably.

It can therefore be assumed that, if the value of E_p does not vary greatly, it is the elastic strain energy E_e that

(*Concluded on page 86*)

Experimental Determination of Flow Patterns in Centrifugal Pumps

By H. P. LEWINSKY-KESSLITZ

From *Österreichische Ingenieur-Zeitschrift*, Austria,
Vol. 3, No. 10, October 1960,
pp. 330–336, 12 illustrations.

EXPERIMENTAL investigations are of particular importance in the design of centrifugal pumps, because the effects of viscosity are not easily taken into account in calculations. However, an experimental study of flow in impellers also gives rise to considerable difficulties, and the object of this paper is therefore to present an improved method of determining flow conditions, with examples of the measured results.

Flow Conditions in an Impeller

In this investigation, a centrifugal pump (Fig. 1), fitted with an impeller having blades of simple curvature, was used. The pump, with a volute casing and no diffuser, had a nominal capacity at 1450 rpm of 72 m³/hr with a head of 9·5 m of water. Air, however, was used as the working medium, as it was considered that the test results could be converted to operation with water, because of the small relative velocities involved, and despite the difference in Reynolds numbers.

The direction of relative flow was first measured photographically at 52 positions in a passage of the impeller, after which measurements were made of the static pressure at these 52 positions through holes in the impeller wall and also of the total pressure at these positions by means of Pitot tubes whose positions were adjusted in accordance with the directions of relative flow first determined.

Various methods of obtaining flow patterns have been described by several investigators, some of whom have used open impellers with a vertical shaft and a free water surface at low running speeds, while others have obtained flow patterns by means of chalk preparations or by changes in the appearance of painted surfaces, and still others have used small tags or pennants to provide visual indications of flow. However, as none of these procedures seemed suitable for use in this particular investigation, three methods, involving respectively the use of incandescent particles, sooty gas flames, and smoke trails, were tried out.

In the incandescent-particles method, finely powdered charcoal was fed from a mechanical vibrator into a gas flame. The resulting incandescent particles were aspirated by the pump and their relative trajectories recorded photographically. This method gave good photographs of the paths followed by the incandescent particles but, owing to inertia effects, the trajectories deviated from the true flow lines of the working medium.

In the method using a sooty gas flame, a long flame of town gas, producing a considerable amount of soot, was directed into the suction side of the pump, where it was deflected through 90 deg. as a result of the flow, sucked through the impeller, and photographed in the same way as in the incandescent-particles method.

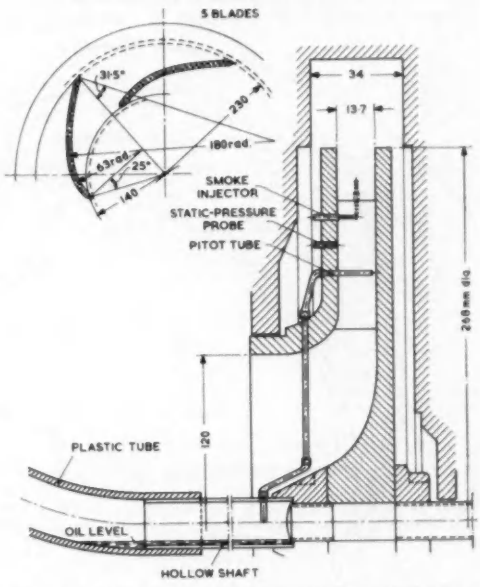

Fig. 1. Section through the experimental pump impeller.

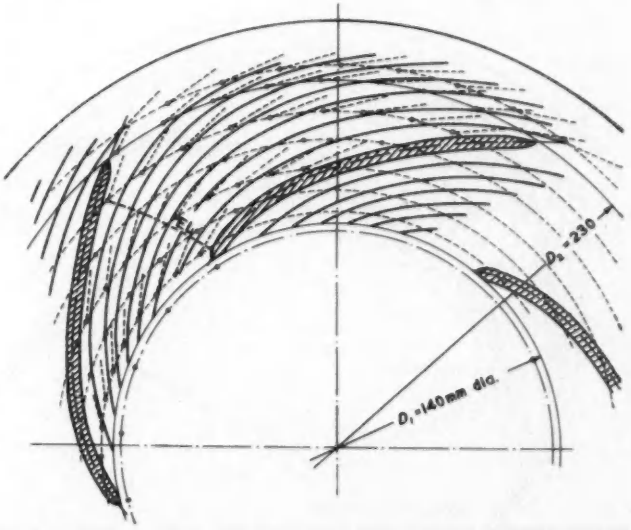

Fig. 2. Typical example of the flow pattern obtained with the smoke-trail method, with the pump operating at rated capacity. E.L. = equipotential line.

Because of the non-uniform temperature distribution, which would have been very difficult to determine, this method did not produce results suitable for numerical evaluations. In a modification of this method, small nozzles were introduced into the measuring channel, with orifices perpendicular to the direction of flow, town gas being supplied to these nozzles through the hollow pump shaft. To minimize thermal effects, only one nozzle was used for each photographic record, and the flow in the entire channel cross-section was obtained by superimposing the photographs of the nozzle at various positions. Because of extinction of the flame, the method was applicable only at flow velocities below 7 m/sec, and was therefore unsuitable for this investigation.

In the smoke-trail method, a smoke cartridge was electrically ignited in a closed vessel, and the smoke was introduced into the orifices of small tubes (1·2 mm in diameter) perpendicular to the impeller shroud, after passing through a filter and then through the hollow pump shaft. Illumination was provided in a plane at right-angles to the axis of rotation through a window in the casing. Photographs were taken at various radial distances from the pump axis, the results enabling the directions of relative flow to be determined with an accuracy of about ± 1 deg. This method was found suitable for flow velocities up to 120 m/sec, a typical example of the results obtained at rated capacity being shown in Fig. 2.

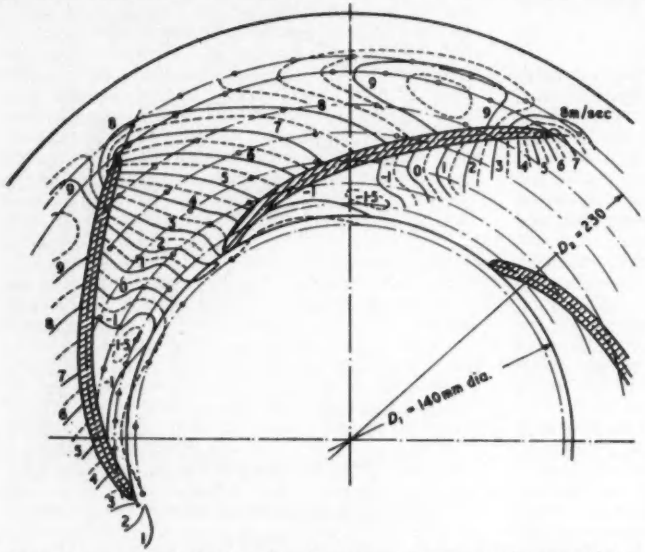

Fig. 3. Pressure distribution in an impeller passage of the pump when operating at rated capacity.

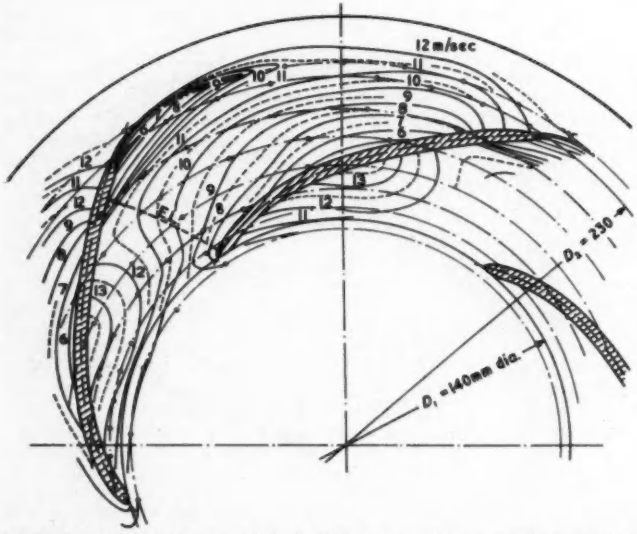

Fig. 4. Relative velocity pattern in an impeller passage of the pump when operating at rated capacity.

Static pressure and total pressure were the next variables that had to be determined. Pressure measurements in rotating impeller passages have been carried out by various investigators, who have, however, measured only the static pressure and determined velocities by calculations from energy considerations. These calculations have assumed an ideal flow without flow separation, so that the validity of the results is open to question. The procedure used in the present investigation differs from other procedures in that, as the directions of flow were known from the photographic records, it was also possible to determine exactly the total pressure and hence the velocity at every position in the passage. The total pressure measurements were first determined for three sections, into which the passage width was regarded as being subdivided. In view, however, of the very small discrepancies between the results for these three sections, it was found that sufficiently accurate indications could be obtained from measurements along the middle section only.

The pressure distribution and relative velocity patterns thus obtained, with a nominal flow rate of 72 m^3/hr at 1450 rpm, are shown in Figs. 3 and 4 respectively. In addition, a pattern of constant-energy lines was determined, these lines representing the energy content per kilogram of fluid pumped and, as such, can be called lines of constant internal head. Broadly speaking, this pattern is fairly similar to the pressure pattern in Fig. 3, except towards the outer end of the underside of the blades, where it has the additional long and narrow closed contours of the relative-velocity pattern in Fig. 4.

Fig. 5 shows the results obtained, with the pump operated at rated capacity, at nine equally spaced measuring positions on the outer blade diameter (230 mm) and includes, in addition to curves of relative velocity W and static head H_{stat}, curves of the relative flow angle β, of the absolute flow velocity C, of the meridional component C_m of absolute velocity C, of the total head $H = (p/\gamma + C^2/2g)$, where p = pressure [kg/m²] and γ = density [kg/m³], and of the parameter UC_u/g, where U = peripheral speed [m/sec] and C_u = peripheral component of absolute velocity C. Similar curves are plotted in Fig. 6 for five equally spaced measuring positions on an intermediate diameter of 175 mm, and in Fig. 7 for five positions near the blade inlet diameter, i.e., at 148 mm.

In the case of the conditions at the outer blade diameter (Fig. 5), the mean value of the relative flow angle β is about half that of the blade angle (31·5 deg.), so that the absolute flow outwards is at a much steeper angle than might have been expected. It was found, in agreement with the results reported by Kearton[1], that the direction of relative outflow velocity was not appreciably affected by the discharge rate, and therefore the loss factor (represented by the ratio of the peripheral component of the absolute velocity just beyond the passage outlet to the corresponding velocity at the blade-tip diameter) drops when the discharge is increased.

With regard to the conditions at an intermediate diameter, Fig. 6 shows that the relative velocity W decreases nearly linearly from the suction side to the pressure side over the circular arc of the diameter considered, and also that there is a nearly linear increase in the static head H_{stat} from the suction side to the pressure side. In the case of the conditions near the blade inlet diameter (Fig. 7), the velocity distribution is no longer approximately linear, owing to the finite thickness of the blades and to pressure equalization. Under the conditions prevailing at the outer blade diameter, Fig.5 shows that the maximum value of relative velocity W occurs on the pressure side of the blade, rising from position (1) to position (3), where it levels out, and then rising again between positions (8) and (9). As a result, in combination with the Coriolis forces, the main portion of the flow is directed towards the pressure side of the

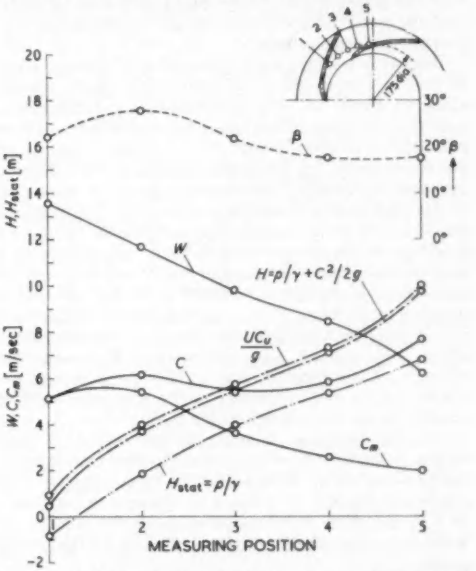

Fig. 6. Results obtained with the pump operating at rated capacity at five measuring positions on an intermediate diameter.

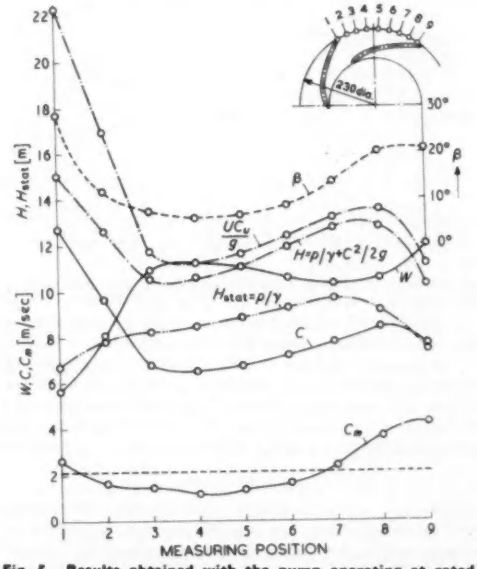

Fig. 5. Results obtained with the pump operating at rated capacity at nine measuring positions on the outer blade diameter.

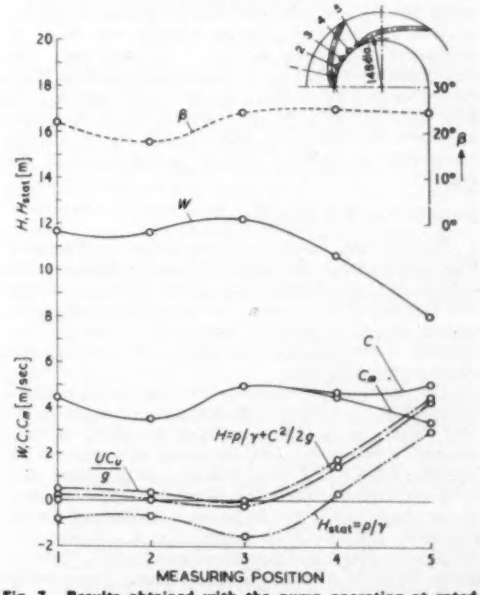

Fig. 7. Results obtained with the pump operating at rated capacity at five measuring positions near the blade inlet diameter.

blade. Also, Fig. 5 shows that, owing to pressure equalization over the blade tips, the curve of static pressure H_{stat} has its maximum near the pressure side of the blade, i.e., at position (7).

Fig. 3 indicates the positions on the suction side which are particularly susceptible to cavitation; it also shows that the highest pressure in the passage occurs near the pressure side of the blade, and that, at intermediate radii, the pressure along the equipotential lines is approximately constant.

Fig. 4 shows that the highest relative velocity is not at the blade inlet, but on the underside, about midway along the blade. A fluid particle entering, for instance, near the underside of the blade will accordingly first be accelerated and then slowed down. At the upper end of the underside of the blade, the velocity pattern shows a region of low relative flow velocities, so that a separation of the relative flow evidently occurs over approximately the last third of the suction side, and this also leads to a reduction in the relative outflow angle. A particle on a line midway across the passage width will be subjected only to small changes in velocity (e.g., the line corresponding to 10 m/sec in Fig. 4), whereas on the pressure side, in the direction of the flow, there is a slowing-down action followed by an acceleration. The minimum velocity on the pressure side of the blade is approximately on the same diameter as the maximum relative velocity on the suction side of the blade.

As the discharge is reduced, the region of high relative velocities on the suction side is displaced towards the pressure side. With complete throttling, the flow conditions become unstable, i.e., either a through-flow or a reverse flow occurs, depending on the momentary position of the impeller passage relative to the volute casing.

Patterns of constant-energy lines (constant internal head contours) showed two regions of large energy content, i.e., one near the dead-water region close to the blade tip on the underside (where, owing to the low relative velocity, the absolute velocity and hence its peripheral component are large) and the other over approximately the last third of the upper side of the blade, caused by the high static pressure in this region. The high internal head in the region on the underside, however, has but little effect, since the meridional component of absolute velocity is also small in this region.

Flow in the Volute Casing

Pressure and velocity patterns in the volute casing were determined at five different cross-sections. As the casing had a rectangular cross-section, sufficient accuracy was obtained with measurements taken only in the middle section in a plane perpendicular to the pump axis, the distance from the tongue of the casing to the blade outlet diameter being 33 mm.

The measured pressure and velocity distribution curves (Fig. 8) indicate approximately constant values only when the discharge is equal to about half the nominal rated value. At the outer diameter of the impeller, a pressure drop occurs at high discharge rates from the tongue towards the direction of flow, whereas at low discharges a rise in pressure is obtained in this direction. Because of the interchange of momentum at the impeller outlet, and despite frictional effects, the total energy increases in the direction of flow. The velocity distribution around the impeller shows the opposite trend. From these results, it can be concluded that non-steady flow conditions exist in the blade passages of pumps with volute casings.[2,3,4]

The arrangement of the glass window in the inner impeller shroud made it necessary to extend the diameters of both shrouds beyond the outlet diameter of the blades, and this probably had an appreciable effect on the exchange of momentum. With the procedure used, it was only possible to determine the flow fluctuations in the impeller passage by means of the measurements of pressure distribution in the volute casing. Even if photographs had been taken at various positions in the passage, they could not have been evaluated, since the pressures were average values over a period of time. Thus, only flow fluctuations at the inlet of the volute casing could be determined. The mean velocities over the impeller periphery were therefore not accurately evaluated, but check calculations showed that the errors were not unduly large.

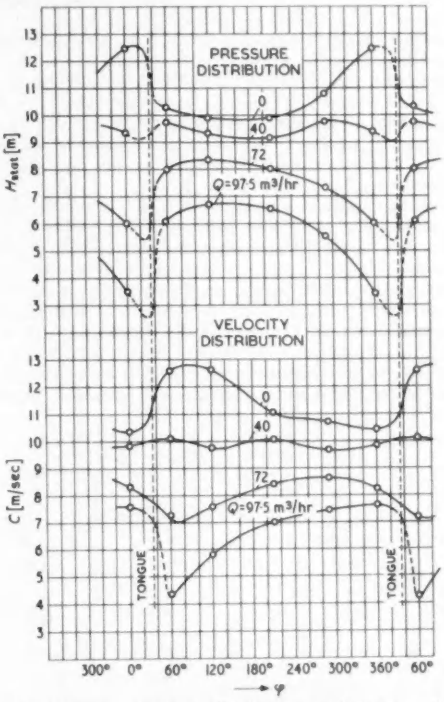

Fig. 8. Pressure and velocity distributions in the volute casing, just beyond the impeller outlet, at various discharge rates

These check calculations were made by determining the values of the discharge from Pitot-tube measurements in the impeller passage at different radii and comparing them with the discharge measured in the delivery pipe by means of a calibrated orifice. Agreement was found to be within 1%. In addition, the internal head H_i was computed from the blade pressure, using the relation

$$H_i = (\omega z/Q) \int \Delta h \; br \; dr$$

where ω = angular velocity, z = number of blades, Q = discharge rate, Δh = difference in height, b = channel width, r = radial distance from the inner radius r_1, of the blade to its outer radius r_2. The result was then compared with the integral of the energy content of the

flow at the impeller outlet, and agreement was again obtained to within 1%.

Evaluation of Test Results

The losses in the impeller were calculated from the difference between the theoretical head H_{th} (impeller power required to pump 1 kg/sec of fluid) and the internal head H_i. The theoretical head is

$$H_{th} = \frac{1}{2\pi C^*_m g}\int (U_2 C_{3u} - U_1 C_{0u}) C_{2m}\ d\varphi$$

$$= 14{\cdot}02 \text{ m}$$

where $C^*_m = (1/2\pi)/C_m d\varphi$, (integrals between the limits $\varphi = 0$ and 2π), C = absolute velocity [m/sec], $g = 9{\cdot}81$ m/sec^2, U = peripheral velocity [m/sec], and φ = polar angle (0 deg. for the radius passing through the largest volute cross-section). The subscripts are m = meridional, u = peripheral, 0 = position at impeller eye, 1 = position at blade inlet, 2 = position at blade outlet, and 3 = position just beyond blade outlet.

The internal head H_i is determined from

$$H_i = \frac{1}{2\pi C^*_m}\int \left(\frac{p}{\gamma} + \frac{C^2}{2g}\right) C_m\, d\varphi$$

$$= 12{\cdot}02 \text{ m}$$

where p = pressure [kg/m^2], γ = density [kg/m^3], and the integral is between the limits 0 and 2π. Consequently, with a discharge of 72 m^3/hr, the loss of head in the impeller is $(14{\cdot}02 - 12{\cdot}02) = 2$ m.

The loss in the volute casing was determined from the difference between the flow energy measured at the impeller periphery and the flow energy in the last volute cross-section, the resulting value being 1·40 m. In addition, the loss in the discharge branch, which increased in cross-section from 24·1 to 50·2 cm^2, was computed from the difference in flow energy between its inlet and outlet sections. For a discharge rate of 72 m^3/hr, this gave a loss of 1·12 m.

The loss factor ε (equal to C_{3u}/C_{2u}) was calculated from the measured values of head and discharge and from the impeller dimensions. This value was compared with the ε -values determined with the aid of various empirical formulae [2,5,6] and also with a new formula proposed by the author, i.e.,

$$\varepsilon = 1 - \frac{k_1}{zC_{2u}}(k_2 U_2 - W_2 \cos\beta_2)$$

where $k_1 = 5$ and $k_2 = 1 - (\psi/2\eta_h)$, ψ being the head coefficient and η_h the hydraulic efficiency. The empirical value of k_2 depends on the specific speed n_s, and proposed values of k_2 for volute-type pumps without a diffuser are 0·50 for (metric) n_s -values between 60 and 80, 0·52 for n_s -values betewen 80 and 130, 0·54 for n_s-values between 130 and 150, and 0·56 for n_s-values between 150 and 160.

The value of $1/\varepsilon$, as measured for the pump under investigation, was 1·78, the corresponding values being 1·60, as determined by Eck's formula, 1·69 by Stodola's formula, 1·71 by Pfleiderer's formula, and 1·73 by the author's formula.

The comparison was extended to six other volute-type pumps, with specific speeds n_s ranging from 66 to 159, for which the data were available. It appears that, for the examples considered, the author's formula gives a somewhat closer agreement with the measured results, the scatter being within ±3%.

In addition, the resultant radial thrust F_{rad}, acting on the impeller, as a result of the non-uniform pressure distribution around the impeller periphery, was determined. This thrust causes an additional load on the shaft and bearings, and its value was obtained from

$$F_{rad} = \sqrt{F_x^2 + F_y^2}$$

where $F_x = (\gamma\pi/180)\ R_3 B_2 \int H_{stat} \cos\varphi\ d\varphi$

and $F_y = (\gamma\pi/180)\ R_3 B_2 \int H_{stat} \sin\varphi\ d\varphi$

where R = radius, B = width, and γ = density, the integration limits being from $\varphi = 0$ to 2π.

TABLE I: COMPARATIVE VALUES OF F_{rad} AT DIFFERENT DISCHARGE RATES

	Discharge Rate [m^3/hr]				
	0	20	40	72	97·5
Thrust angle [deg.]	163	155	135	350	358
F_{rad} (measured) [kg]	24·5	14·8	1·7	21·3	32·2
F_{rad} (Stepanoff) [kg]	33·9	31·6	19·8	0	8·8

Comparisons of the value of F_{rad}, as measured and as determined by Stepanoff's empirical formula[4], for different discharge rates, are given in Table I.

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Improving Diamond-Wheel Performance in Electrolytic Machining

(*Concluded from page 89*)

wear reduces. Because of initial wear, it is sometimes necessary to deplate the wheel a second time to re-establish the desired gap. Deplating should, however, be kept to a minimum, as excessive deplating can cause the diamonds to loosen from the matrix.

Once the new diamond wheel has been run in and the spacers flattened to a slow-wearing condition, the wheel requires little maintenance. The wheel face should be cleaned occasionally with a pumice or abrasive stick to remove oxides. The rate of feeding work into the wheel should be such that stock removal results from optimum electrolytic action, rather than from the abrasive action of the wheel.

Important wheel-care precautions for the machine operator can be summarized as follows:—

(1) Never attempt to machine a piece when the current is reversed. The machine should be in reversed polarity only when the deplating shoe is being used.
(2) Avoid leaving the wheel charged when it is not rotating. Touching a charged wheel with a workpiece when the wheel is not turning will cause damage to the wheel.
(3) Maintain an ample flow of electrolyte between the wheel and the workpiece. Poor cutting characteristics and excessive arcing are indications that elecrolyte flow is too low.

When these precautions are followed, optimum wheel life and performance should be obtained.

Applications of Flexible Magnets

By A. R. GARDNER

From *Product Engineering*. U.S.A.,
Vol. 32, No. 2, January 9, 1961,
pp. 65–68, 5 illustrations.

FLEXIBLE magnets, comprising a wide range of rubber or plastics materials, magnetized in bands, strips, or almost any other pattern and made in a variety of sizes, are now available for use in many new applications.

Rubber incorporating magnetic particles has been on the market for some time, but the range of elastomeric materials containing such magnetizable particles as barium ferrite is now much wider, and production techniques have been improved to the point where permanent magnets—flexible and surprisingly strong—can be developed. Furthermore, these materials, which were used at first only in closure mechanisms and coverings for machine pick-up rolls, are now being developed for products ranging from bicycles and toys to conveyor belts and oil filters. Electrical, as well as structural, applications are on the way, and new suppliers are entering the field.

Many factors contribute to the design value of flexible magnets, which offer light weight, chemical resistance, and ease of fabrication that cannot be matched by any of the hard materials; also, in some applications, they cost much less, and some of the newer materials come surprisingly close to hard magnets in coercive force.

It is possible, for instance, to obtain materials with a maximum energy product of 2×10^6 gauss-oersteds—a very respectable figure, compared with solid ceramic magnets. Several types have a coercive force in the range from 1150 to 1300 oersteds—again close to that of many ceramic magnets and nearly twice the figure given for Alnico V. Their residual induction may range from 1600 to 2100 gauss or more.

Another advantage of flexible magnets is that they can be magnetized in a wide variety of patterns—on one or both sides, in crosswise stripes, or with north and south poles positioned along sides, edges, and corners. However, it should be noted that the strongest pull is obtained with a one-sided magnetization on the broadest face. In addition, although their cost varies considerably, it is possible to purchase $\frac{1}{2} \times \frac{1}{16}$ in. strip in the U.S.A. for as little as 10 cents per foot, and fabrication is usually a simple matter.

Despite these advantages, it should be appreciated that flexible magnets are generally not as strong as solid magnets, and that their form and magnetic-flux configuration are different. As a result, they usually cannot be employed as direct substitutes for the solid materials. As a matter of fact, mere substitution would probably waste one of their biggest advantages, i.e., their sealing and gasketing action, as well as holding power.

In general, small flexible magnets should not even be considered where heavy weights or strong pulls are involved. Most flexible magnets in thin strips will hold little more than half a pound, whereas a similar solid magnet can hold several times as much. On the other hand, when a fairly thick block or long strip of flexible material can be used, the pull can be quite considerable. Furthermore, in the case of configurations such as small rectangles, their holding power can be increased by the provision of a steel back-up plate. In this connection, it may be mentioned that, although the insertion of a steel strip does not affect the total pull of a flexible magnet, the holding power decreases rapidly with an increasing air-gap. As a typical example of the strength and weight of these magnets, it may be mentioned that the pull of one group of plastic magnetic materials ranges from 0·08 lb per linear inch with zero air-gap and 0·04 lb per linear inch with a 0·015-in. air-gap for a $\frac{1}{4} \times \frac{1}{16}$ in. strip weighing 0·05 lb per foot, to 0·69 lb per linear inch with zero air-gap and 0·51 lb per linear inch with a 0·015-in. air-gap for a $1\frac{7}{8} \times \frac{1}{4}$ in. strip weighing 0·37 lb per foot.

Because flexible magnets have a higher coercive force than the Alnico types, but a considerably lower residual flux density, they have to be made in a different shape to achieve comparable performance. In general, as compared with metallic magnets, flexible magnets must be considerably larger in cross-section but shorter from pole to pole. The difference in shape, as compared with ceramic magnets, will not be as great, but is still likely to be significant in design.

Other problems in applying flexible magnets relate to the specific base material. For instance, the rubber-based types offer excellent flexibility, but may stiffen on ageing, and may lack resistance to oil. The plastics, on the other hand, may show only minimum bendability in all but the thinnest sections, and may tend to stiffen when cold and soften under heat. In general, none is recommended for use under load at temperatures above 175°F. Even where load is not a factor, temperatures above 200°F are not recommended, since these materials also lose magnetic strength as temperature rises, about 25% being lost by the time 175°F is reached.

Another problem with flexible magnets is that of extension and compression set. It might be expected that, under the force of closure, the rubber-based flexible magnets would tend to show a permanent compression set. Actually, in some cases at least, the reverse is true, flexible magnets sometimes extending or pulling out and preventing closure or interfering with proper mating of parts. One way to get around this problem is to incorporate the magnet in a gasket which will both hold the magnet and compensate for any changes in shape.

Potential Applications

Imaginative proponents of flexible magnetic materials see almost no limit to potential types and applications. Thus, for instance, in the Soviet Union consideration is being given to magnets in paste form that can simply be moulded to shape like modelling clay. One possible application of these magnets is in midget motors and transformers, in which the plastic parts serve as insulators as well as magnets, helping to reduce overall size. Similarly, one American supplier is working on a spray-able iron-powder composition which can be deposited on non-magnetic materials to provide a surface that will attract a magnet, though it may not serve as a magnet itself.

Flexible magnets are being offered with a variety of facings and backings, e.g., paper coverings and pressure-sensitive adhesive. In fact, improvements in materials now on the market and in fabrication techniques are opening up many new industrial applications. For

instance, the relatively low mechanical strength and tendency to flex-cracking of flexible magnets has limited their use in such applications as conveyor belting. Now, however, techniques are being developed for bonding a magnetic cover to a conventional carcass which may help to overcome this limitation. Bonding flexible magnetic strips to very thin, flexible steel backings may open up many design fields, providing an effective compromise between strength and flexibility, and making it possible to take advantage of the cushioning effect of the elastomer.

Other ideas—strictly on the consumer side—might include belts capable of holding at any point where their ends overlap, small magnetic strips which can be dropped, for instance, into a package of cigarettes or wrapped around a pencil for attachment to metal surfaces, e.g., the dashboard of a car, or boxes which will not spill their contents no matter how they are tipped.

The availability of cheap flexible magnetic cord (in the U.S.A., a cord of $\frac{3}{32}$ in. diameter costs only from 3 to 6 cents per foot and weighs about 0·01 lb per foot) may open up a wide variety of applications in the electrical field. Indeed, the electrical applications of flexible magnets are only beginning to be explored. One company, for instance, is working on flexible circuit components for simple electrical devices, while another company has suggested the possibility of turning vehicle wheels into electrical generators by incorporating magnetic strips in the tyres, while yet another company is testing the materials for possible application in computer "memories."

One of the most promising immediate applications for flexible magnets is in individual closures—simple locks and latches—and in relief "valves" that will "give" under pre-determined pressure, and then close themselves automatically when the pressure drops. Here, light weight and ease of fabrication are primary advantages, rather than flexibility itself.

Flexible magnets are being used, in conjunction with plastic gaskets, as full-door liner-closures for refrigerators. However, the use of the magnet alone as both a gasket and a closure must still be considered as an experimental application, as designers have run into problems of discontinuity at the corners and dispersion of the attractive force, so that there is no single, strong pull at a central point, and these problems are still holding back several projected applications. In addition, the question of particle pick-up and its effects on large-size applications is still being evaluated.

The Properties of Plasma-Sprayed Materials

By M. A. Levinstein, A. Eisenlohr, and B. E. Kramer

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Vol. 40, No. 1, January 1961,
pp. 85-135, 11 illustrations.

Within the past few years, interest in high-temperature technology has increased tremendously, and has been stimulated by the severe demand placed on materials for advanced ram-jets, rocket motors, and missile applications. The objective of the investigation described in this paper is therefore to determine some of the mechanical and physical properties of a number of materials with melting points above 4500°F deposited by the plasma-spraying process.

The materials investigated included tungsten and molybdenum (both in wire and powder form), tantalum carbide and hafnium carbide, and cerium oxide, zirconium oxide, and hafnium oxide. Where applicable, determinations were made in the as-received, as-sprayed, and heat-treated conditions and included gas analyses (oxygen and nitrogen) and examinations of microstructure and crystallographic structure.

For spraying tungsten and molybdenum wire, the consumable-electrode, inert-gas unit shown schematically in Fig. 1 was used. In this gun, which is extremely simple in design and construction, a 0·040-in. wire is introduced by means of a wire-feed unit incorporating wire-straightening rolls, the wire being directed through a wire-guide in one electrode. A high-frequency arc starter initiates the arc and, under certain conditions of operation, helps to maintain it. The arc is formed between the wire and the water-cooled nozzle and is stabilized by the flow of high-pressure argon gas.

The gun can be operated with various power sources on either direct or alternating current. High-density deposits have been obtained with the wire charged either anodically or cathodically. The most stable operating conditions were achieved with the wire negative and when a d.c. motor-generator was used as the power source. The wire-feed rate could be varied between 100 and 450 ipm, and the current between 290 and 490 A. With an arc voltage of 40 V and a gas pressure of 50 psi, the deposition rate varied between 2·55 kg/hr at 100 ipm and 290 A, to 11·73 kg/hr at 450 ipm and 490 A.

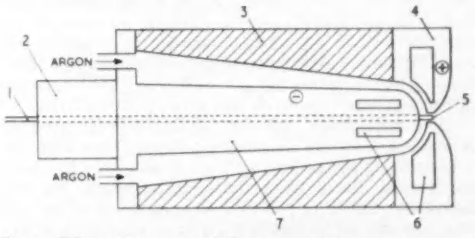


Fig. 1. Schematic lay-out of the gun used for spraying wire.
(1) Tungsten wire. (2) Wire drive.
(3) Insulator. (4) Front electrode.
(5) Arc. (6) Water-cooling chamber.
(7) Electrode and wire guide.

The gun used for spraying powder, shown schematically in Fig. 2, operates on the non-consumable-electrode arc principle. The plasma is formed in the throat of the water-cooled nozzle, a hole being provided approximately $\frac{1}{4}$ in. from the end of the nozzle for the introduction of the powder. The gun is operated from two 600-A motor-generators and is rated at 40 kW.

Whereas the wire gun can be operated only with argon, a number of plasma-forming gases can be used with the powder gun. Of these, it would appear that hydrogen would be the most suitable from the point of view of its high enthalpy and heating efficiency, coupled

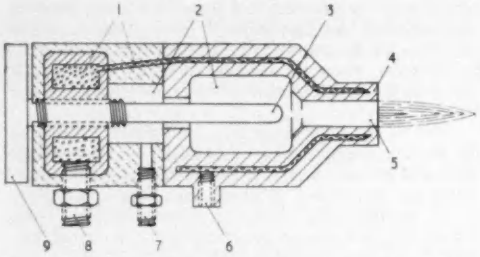


Fig. 2. Schematic lay-out of the gun used for spraying powder.
(1) Cooling-water jacket.
(2) Plasma-forming gas.
(3) Electrode.
(4) Copper-alloy nozzle.
(5) Arc.
(6) Electrical connection and cooling-water outlet.
(7) Plasma-gas inlet.
(8) Electrical connection and cooling-water inlet.
(9) Electrode adjustment.

with its comparatively low cost. However, when hydrogen alone is used as the plasma-forming gas, it has a very erosive effect on the nozzle, greatly reducing its life. For long nozzle life, a mixture of nitrogen with 10% by volume of hydrogen is effective, and this mixture was used in much of this investigation.

Tungsten and Molybdenum

The tungsten and molybdenum specimens were prepared by spraying them on an aluminium tube of 0·75 in. o.d., the tubular configuration being chosen because it permitted internal cooling during deposition. Aluminium was selected because it can readily be leached from the sprayed deposits by alkaline reagents, without contamination or reaction with the sprayed metals. The aluminium tube served as a mandrel, which was chucked in a lathe and rotated to ensure uniform deposition.

For the wire-sprayed specimens, 0·040-in. wire was used, the wire speed being 100 ipm. In the case of the powder specimens, the powder-feed rate was 6 lb/hr, using 10 cu ft/hr of nitrogen as the powder-carrier gas. The plasma-forming gas, comprising a mixture of nitrogen with 10% hydrogen, was fed at a rate of 100 cu ft/hr, the calculated plasma temperature being 9500°F with a power input to the gun of 28 kW. The distance of the gun from the work was between 2 and 3 in.

The high-power operation of the powder-spraying equipment produced a hotter and longer flame than the wire-spraying equipment, and it was necessary to divert the plasma flame from direct impingement on the deposited material to prevent overheating and oxidation. This was effected by directing a narrow blast of air at the plasma after exit, the blast pressure being adjusted to divert the plasma without deflecting the particles.

Under the above conditions, cylindrical specimens, 4 in. long with a 0·300-in. wall, were produced. Removal from the mandrel was accomplished by leaching in a cold 50% NaOH solution for approximately 30 min. Longitudinal sections were cut from the cylinders, and some of these sections were set aside for evaluation of the "as-sprayed" material and the balance of the sections was heat-treated. In all cases, the wire-sprayed specimens of both tungsten and molybdenum were heat-treated in hydrogen at 3600°F for 1 hr. The powder-sprayed tungsten was heat-treated at 4000°F in a vacuum for 2 hr, while the powder-sprayed molybdenum was heat-treated in hydrogen for 2 hr at 2150°F and also in a vacuum for 2 hr at 4000°F.

Gas determinations for oxygen and nitrogen were made on both the as-sprayed and heat-treated materials. The results indicated that, while nitrogen pick-up was relatively low during the spraying operation, there was considerable oxygen pick-up, even though the wire was sprayed with argon gas. It is realized that some of this pick-up may have been due to oxidation of the deposited material while the specimen was being prepared. However, this can only be determined if the spraying is done in a tank under an inert atmosphere.

Density determinations were made on both the as-sprayed and heat-treated materials, using a water-displacement method, the accuracy of which was verified by comparison with accurately machined specimens by direct weighing. The as-sprayed densities of the wires were approximately 2% greater than those of the powders. The 3600°F sintering treatment increased the density of the wire-sprayed deposits by from 2·0 to 2·5%, and the powder-sprayed deposits by from 1·5 to 3·0%, as shown in Table I.

TABLE I: DENSITY AND HARDNESS OF TUNGSTEN AND MOLYBDENUM

Material	Density [% theoretical]		Vickers Hardness	
	As-Sprayed	Heat-Treated	As-Sprayed	Heat-Treated
Tungsten				
Wire	85·0–87·0	87·0–89·0	246–263	238–255
Powder	83·0–84·0	84·5–85·5	330–390	162–200
Molybdenum				
Wire	88·0–89·0	90·5–91·5	168–183	155–159
Powder	86·2–87·1	89·3–90·2	321–368	125–175

Hardness values were obtained with a Vickers hardness tester, using a 1-kg load and specimens which were metallographically mounted and polished. Annealed wrought tungsten has a hardness of 375 VHN and annealed wrought molybdenum a hardness of 165 VHN. The lower values obtained on the sprayed material (see Table I) may be due to its porosity.

Photomicrographs of the as-sprayed deposits of tungsten wire in both the unetched and etched condition showed that the structure was typically lamellar, with scattered large voids throughout the structure, as indicated in Fig. 3, which shows the bonding between the lamellar and the sub-grain structure of the individual platelets. In the case of the heat-treated specimens, however, some changes in the structure were noted, considerable recrystallization taking place, though there was still evidence of the original lamellar structure. The structure of the as-sprayed molybdenum wire showed fewer large voids than the as-sprayed tungsten wire, while the heat-treated specimens completely eliminated the lamellar structure through the mechanism of recrystallization and grain growth.

The structures of the as-sprayed deposits of both tungsten and molybdenum in powder form were significantly different from those of the wire-sprayed materials, the lamellae being smaller and of more uniform size. In addition, the voids were smaller and were much more uniformly distributed. Their heat-treated structures also showed considerable differences. Thus, the recrystallized grain size of the powder-sprayed tungsten was much finer than that of the wire-sprayed tungsten, despite the higher heat-treatment temperature and the longer period involved. However, in the case of the powder-sprayed molybdenum deposits, these same heat-treatment conditions produced a massive grain growth, as shown in Fig. 4.

Fig. 3. (left) Electron micrograph of as-sprayed tungsten wire (×3000)

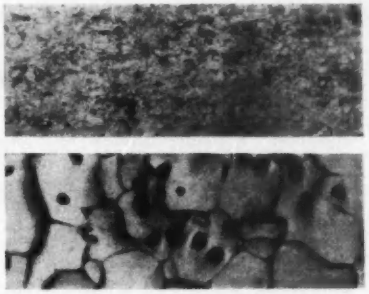


Fig. 4. (right) Molybdenum powder (top) as-sprayed, etched, and (bottom) after heat treatment for 2 hr at 4000°F in a vacuum (×50)

Tensile properties were determined only on the heat-treated materials, since the as-sprayed deposits were too brittle to be machined into tensile specimens. A button-head type of tensile specimen was used, having a 1-in. gauge length and a 0·160-in. diameter. Even the heat-treated specimens needed special precautions in machining, very light feeds being required to prevent breakage. Tensile tests were carried out on the heat-treated specimens at room temperature and also at elevated temperatures, the tests at elevated temperatures being conducted in an evacuated capsule at an absolute pressure of 1×10^{-4} mm Hg. A head-travel rate of 0·01 ipm was maintained during testing.

TABLE II: TENSILE STRENGTH OF HEAT-TREATED MATERIALS

Material	Tensile Strength [psi] at				
	75°F	2000°F	3000°F	3500°F	4500°F
Tungsten					
Wire	5,200	10,500	—	—	—
Powder	6,700	15,300	7,100	3,800	1,600
Molybdenum					
Wire	13,700	15,600	—	—	—
Powder[1]	—	6,600	2,000	—	—
Powder[2]	30,500	10,500	—	—	—

(1) 2 hr at 2150°F in hydrogen. (2) 2 hr at 4000°F in a vacuum.

As already mentioned, the wire-sprayed specimens of both tungsten and molybdenum were heat-treated for 1 hr at 3600°F in hydrogen, while the powder-sprayed specimens of tungsten were heat-treated for 2 hr at 4000°F in a vacuum, and the powder-sprayed molybdenum for 2 hr at 2150°F in hydrogen and for 2 hr at 4000°F in a vacuum. The results of the tests for tensile strength are given in Table II, while those for a number of tests on yield strength, elongation, and reduction of area at different temperatures are given in Table III.

TABLE III: YIELD STRENGTH, ELONGATION, AND REDUCTION OF AREA

Material	Test Temperature [°F]	2% Yield strength [psi]	Elongation [%]	Reduction of Area [%]
Tungsten				
Powder	4,500	1,500	30·0	16·6
Powder	3,500	3,300	9·7	7·6
Powder	3,000	5,600	8·0	7·5
Molybdenum				
Powder[1]	3,000	1,700	2·0	2·0
Powder[2]	2,000	5,300	23·0	24·0

(1) 2 hr at 2150°F in hydrogen. (2) 2 hr at 4000°F in a vacuum.

It is significant to note that the tensile strength of the wire-sprayed sample of molybdenum was about 50% higher than that of the powder-sprayed sample heat-treated for 2 hr at 4000°F in a vacuum, but that the former had no ductility. Apparently, the high sintering temperature and longer heat-treating time are needed to impart ductility to the material. The effects of high sintering temperature and longer sintering are more pronounced on the room-temperature strength of the molybdenum specimens, where the 4000°F sinter for 2 hr yielded a tensile strength of 30,500 psi, compared with 13,700 psi after the 1-hr heat treatment at 3600°F. However, this may be due, in part, to differences in the as-sprayed structure, since the higher tensile strength refers to the powder-sprayed molybdenum and the lower strength to the wire-sprayed molybdenum.

X-ray diffraction studies showed the lattice parameter a_0 of the wire-sprayed tungsten to be 3·1648 Å, i.e., identical with the ASTM accepted value for tungsten. The powder-sprayed tungsten had a slightly higher value for the lattice parameter, i.e., $a_0 = 3{\cdot}1656$ Å. The value of the lattice parameter in the case of the heat-treated wire-sprayed molybdenum was 3·1534 Å, which is slightly larger than the accepted value of 3·1472 Å.

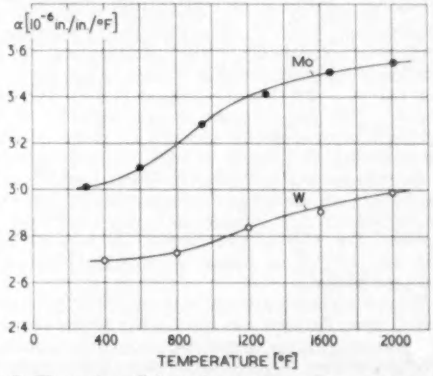


Fig. 5. Thermal coefficient of expansion α of sprayed tungsten and molybdenum as a function of temperature.

Measurements of thermal expansion were carried out on bars of tungsten and molybdenum, 0·190 in. in diameter and 2·5 in. in length, from room temperature to 2100°F, expansion being measured with a commercial dilatometer. The results, showing the thermal coefficient of expansion α of sprayed tungsten and molybdenum, as a function of temperature, are given in Fig. 5.

Hafnium and Tantalum Carbides

The carbides selected for investigation were hafnium carbide, with a melting point of 7030°F, and tantalum carbide, with a melting point of 7010°F. The initial specimens were sprayed with the powder gun under the same spraying parameters used for spraying tungsten and

molybdenum powder, using a mixture of nitrogen with 10% by volume of hydrogen as the plasma-forming gas. Examination of the microstructure of the deposited hafnium carbide showed the presence of more than one phase, indicating that some transformation of the hafnium carbide had occurred during the spraying operation. A similar condition was observed with the sprayed tantalum carbide. Before proceeding with any evaluation of properties, it was necessary to determine the nature of the transformation that had taken place.

X-ray diffraction patterns of the as-received hafnium carbide and tantalum carbide powders were first studied to establish their purity. In each case, the patterns showed only the lines for hafnium carbide and tantalum carbide respectively. No other compounds or phases were detected.

The X-ray diffraction patterns produced by the sprayed materials were poor in quality, owing to microstrains and distortions in the lattices. By heat-treating the deposits at 2000°F in a vacuum, resolution was improved and Hf (C,N), HfO_2, and Hf were detected in deposits from the HfC powder, and Ta_2C and Ta in the deposits for TaC powder. In the latter case, no TaC was found in the deposit.

From these results, it is apparent that there is some dissociation of the HfC and TaC at the high plasma temperature. This was confirmed by chemical analysis of the deposited materials, which showed that the deposited hafnium carbide contained 94·1% hafnium, 2·92% carbon, 0·858% nitrogen, and 1·88% oxygen, while the tantalum carbide contained 93·0% tantalum, 1·12% carbon, 0·376% nitrogen, and 1·96% oxygen.

It should be noted that the stoichiometric composition of HfC is 93·6% Hf and 6·31% C, while that of TaC is 93·77% Ta and 6·23% C. Apparently, there is a considerable loss of carbon during the spraying operation as a result of dissociation. The decomposition of the tantalum carbide proceeded to a much greater extent, in that less than 20% of the original carbon had been retained. The high nitrogen content (0·858%) of the deposited hafnium carbide confirms the presence of the complex Hf (C,N), since the maximum retained nitrogen in the tungsten and molybdenum deposits was 0·103%. The 0·376% nitrogen content present in the deposits from TaC powder would indicate that some TaN may be formed. The high oxygen contents in both deposits (1·88 and 1·96%) are strong evidence that HfO_2 and TaO_2 are present.

Since it was demonstrated that the nitride was being formed when nitrogen was used as the plasma-forming gas, subsequent spraying was conducted with an argon-hydrogen mixture to form the plasma. The patterns of these deposited materials were appreciably different, the sprayed HfC powder showing a major amount of HfC and minor amounts of HfO_2, while the deposit from the TaC powder showed primarily TaC with some Ta_2C. Considerably more work is to be carried out in this area before fully accurate data are available.

Cerium, Zirconium, and Hafnium Oxides

Work on the oxides of cerium, zirconium, and hafnium has only recently started, and the results to date are rather fragmentary. It may be mentioned, however, that X-ray diffraction studies have been made of sprayed deposits of two oxides, i.e., CeO_2 and ZrO_2. The lattice parameter a_0 of the CeO_2 (face-centred cubic structure) was found to be 5·411 Å, i.e., identical with the ASTM accepted value, while that of the ZrO_2 (cubic structure) was 5·123 Å, as compared with the accepted value o 5·070 Å, the higher measured value in this case being due to the fact that 5% of CaO was added to the ZrO_2 for stabilizing purposes.

TABLE IV: HARDNESS AND DENSITY OF CERIUM, ZIRCONIUM AND HAFNIUM OXIDES

Oxide	Vickers Hardness	Density [gm/cc]	Theoretical Density [%]
CeO_2	168–205	6·58	92·3
ZrO_2	636–805	5·14	92·4
HfO_2	251–313	8·39	86·8

In addition, Vickers hardness and density determinations have been made on CeO_2, ZrO_2, and HfO_2, the results being given in Table IV.

Conclusions

It has been established that materials with extremely high melting points can be sprayed successfully with the arc-plasma equipment used. For the spraying of tungsten and molybdenum, the powder method appears to be more advantageous, the powder deposits having a much more uniform as-sprayed structure and a finer sintered structure than the wire-sprayed material. Although the wire-sprayed deposits are more dense in the as-sprayed condition, no beneficial effects are apparent in subsequent heat treatment. In addition, the price of tungsten and molybdenum powders is approximately one-fifth that of the metals in wire form.

Wire spraying has definite advantages in that deposition rates are significantly higher and that the power requirements are considerably lower. Furthermore, the equipment requirements are relatively inexpensive, compared with the powder-gun equipment.

Appreciable amounts of nitrogen and oxygen were retained in the deposits during the spraying operation. The nitrogen plasma-forming gas was probably the major source of the retained nitrogen, though some nitrogen was aspirated from the surrounding air. The high oxygen contents were due primarily to oxidation of the specimen during spraying and secondarily to oxygen aspirated into the plasma stream. To determine more accurately the sources of oxygen and nitrogen, it would be necessary to carry out the spraying in a controlled-atmosphere tank, and future experiments are planned under such conditions.

High-Velocity Impact Tests with Bullets

(*Concluded from page 76*)

takes up most of the energy of high-velocity impact. This means that there is an improvement in the overall impact resistance of the specimen, and hence also of the elastic limit of the material, which is not a fixed value but varies with velocity. Tests by various investigators have amply proved this point, and have shown that, in rupture tests carried out with increasing rates of load application, the elastic limit of the material increases considerably, reaching values which are twice as high as the normal values, even at moderately increased loading rates.

As a general conclusion, it can be said that, after due allowance has been made for energy losses in vibrations and in mounting arrangements, the present tests show the capacity of materials to absorb considerably increased quantities of elastic strain energy at very high loading rates.

Experimental Investigation into Deep-Drawing with Negative Clearances

By S. A. VALIJEV
From *Strojirenstvi*, Czechoslovakia,
Vol. 10, No. 8, 1960,
pp. 598-604, 14 illustrations.

IT is well known that, because of the limited degree of deformation obtainable in a single draft, the number of drawing operations in conventional deep-drawing processes is necessarily large, sometimes as many as from five to ten, and the productivity of these processes is therefore understandably low. The schematic arrangement of the two most common conventional deep-drawing processes with positive clearances and without substantial wall thinning is shown in Fig. 1, in which Fig. 1a refers to drawing with the use of a pressure plate or blank-holder and Fig. 1b to drawing without the use of a pressure plate. In these processes, the clearance z between the punch and die is either greater than or equal to the original thickness t of the flat or cup-shaped blank, in which a substantial reduction in diameter is made. In a third conventional deep-drawing process (Fig. 2), the wall thickness of a cup-shaped blank is greatly reduced, but its internal diameter remains virtually unchanged.

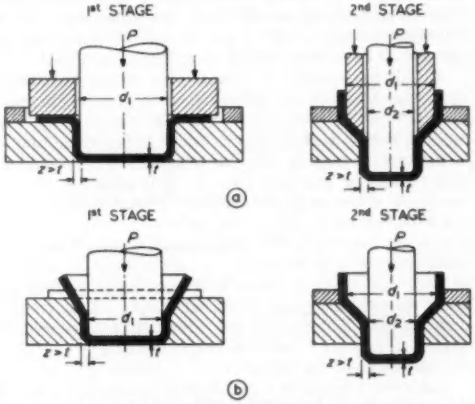


Fig. 1. Schematic representation of two stages of conventional deep-drawing without wall thinning, (a) with a pressure plate, and (b) without a pressure plate.

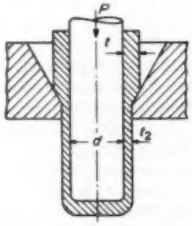


Fig. 2. Schematic representation of conventional deep-drawing with wall thinning.

Deep-drawing with negative clearances (Fig. 3) differs basically from the processes mentioned above in that the clearance z is invariably smaller than the thickness t, so that both the original diameter of the flat or cup-shaped blank and the wall thickness are substantially reduced. Although this method has already been applied in practice and its advantages are fully recognized, comparatively little research has been carried out on the subject and some of the published data contain contradictory conclusions. The object of this article is therefore to summarize the results of an extensive series of experimental investigations carried out with a view to determine the optimum operational parameters for deep-drawing with negative clearances.

For tests on the influence of various design factors on the quality of the finished components, four materials, with a nominal thickness of 1 mm in all cases, were used, i.e., aluminium containing 0·06% iron and 0·26% silicon; brass containing about 62·6% copper and 37·4% zinc; stainless steel containing 0·11% carbon, 16·72% chromium, 8·27% nickel, 0·49% manganese, and 0·49% silicon; and a deep-drawing steel containing 0·07% carbon and 0·30% manganese. Deep-drawing with negative clearances was carried out in two stages without the use of a pressure plate. As it is known that, when drawing without a pressure plate, a die with a conical entry has definite advantages over a die with a radiused entry, since the drawing force P is reduced and the degree of drawing is increased, a cylindrical die, 50 mm in diameter, with a conically shaped entry was used in all tests, in which the drawing ratio, the thickness of the material, the die lubricant used for each particular material, and the drawing speed were taken as constants. The parameters were the apex angle of the conical part of the die, the transition radius between the conical and cylindrical sections of the die, the height of the cylindrical part of the die, the tip radius of the punch, and the clearance between the punch and die.

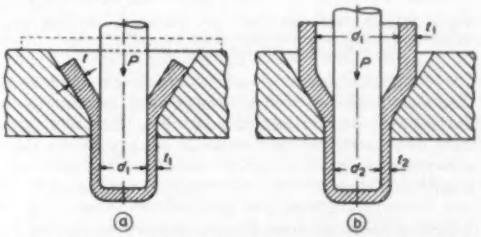


Fig. 3. Schematic representation of deep-drawing with negative clearances, using (a) flat blanks and (b) cup-shaped blanks.

Two series of tests were carried out in each case. In the first of these (Fig. 3a) flat blanks, 87 mm in diameter and 1 mm in thickness, were deep-drawn with the 50-mm punch, the drawing ratio therefore being about 0·55. In the second series of tests (Fig. 3b), cup-shaped blanks were used, these blanks having already been preformed to 64 mm diameter from flat blanks of 113 mm diameter and 1 mm thickness, the final drawing ratio therefore being 0·75.

In order to find the optimum apex angle for the conical part of the die, ten dies with apex angles ranging from 15 to 90 deg. were tested, the average ratio of clearance to thickness z/t being 0·8. Most of the tests on deep-drawing with negative clearances, using flat blanks were successful, except those carried out with an apex angle of 50 deg. for the aluminium and brass, and with

angles up to 35 deg. for the deep-drawing steel and stainless steel, because of the pronounced wrinkling produced on the surface of the components, the degree of wrinkling decreasing with increasing apex angles.

Tests with cup-shaped blanks were also on the whole successful, difficulties being encountered only in the case of stainless-steel components, in many of which wrinkles and other surface defects occurred during drawing. The optimum apex angle for the die was found to be 60 deg. for deep-drawing with negative clearances in the case of the materials investigated and under the conditions of testing. With smaller apex angles, a high scrap rate resulted, and punches of excessive length had to be used.

In deep-drawing processes in general, when the ratio of clearance to thickness z/t is reduced from a value of 1·4 to 1, the drawing force required increases, at the same time causing the lower part of the cup wall to be stretched; this increased drawing force has, however, no influence on strain-hardening of the wall or on the frictional force between the cup and punch. With further reductions in the value of z/t, account must be taken of increased strain-hardening of the wall from the bottom upwards, of increased drawing force, and of a certain thinning of the wall owing to friction. The success of deep-drawing with negative clearances depends largely on the relation between the maximum tensile strain in the wall and its strength.

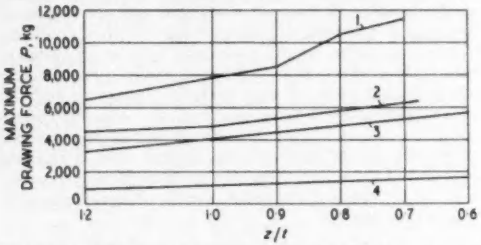


Fig. 4. Relation between maximum drawing force P and ratio, of clearance to thickness z/t for flat blanks of (1) stainless steel (2) mild steel, (3) brass, and (4) aluminium.

In experiments carried out to determine the minimum clearances with which deep-drawing can successfully be carried out without damaging the dies, tests were made with dies having an apex angle of 60 deg. and positive clearances, with z/t values of 1·2 and 1, and also with negative clearances, with z/t values of 0·9, 0·8, 0·7, 0·6 and 0·5. It was found that the minimum value of z/t for the aluminium and brass was 0·6 with flat blanks and 0·7 with cup-shaped blanks. For the deep-drawing steel and stainless steel, the corresponding values of z/t were 0·7 for flat blanks and 0·8 for cup-shaped blanks. The relation between the maximum drawing force P and the value of z/t for flat blanks is shown in Fig. 4, from which it can be seen that the increase in drawing force is comparatively small in the case of the aluminium, brass, and deep-drawing steel, and only in the case of stainless steel is it pronounced, i.e., increasing from about 6500 kg with $z/t = 1·2$ to 11,500 kg with $z/t = 0·7$ under the conditions of testing.

Tests have shown that the difference in the hardness of components produced with maximum and minimum clearances is negligible. It has also been established that the uniformity of wall thickness improves in the case of deep-drawing with negative clearances; thus, for instance, with a z/t value of 1·2, the difference in wall thickness between the bottom and top of the component can be as much as 30%, whereas, with z/t values of from 0·9 to 0·7, the wall thickness is almost completely uniform, though it does exceed the value of the clearance by from about 0·03 to 0·06 mm. This increase appears to be due to the elastic elongation of the die caused by very high surface friction and to the elastic deformation of the cup on leaving the die. Also, it should be noted that, whilst cups drawn with positive clearances have a slightly larger diameter at the rim than at the bottom, cups drawn with negative clearances have a virtually regular cylindrical shape.

In another series of tests carried out to establish the influence of the transition radius between the conical and cylindrical sections of the die, dies with apex angles of 60 deg. and z/t values of 0·7 for flat blanks and 0·8 for cup-shaped blanks were used, the transition radii being 3, 6, 9, 12 and 15 mm. It was invariably found that an increase in the transition radius caused a considerable increase in the drawing force and in some cases led to the formation of uneven rims, owing to irregular metal flow. With a transition radius of 15 mm, only one out of five tests was successful, and in this case the drawing force required was 7200 kg. On the other hand, with a radius of virtually zero, all tests were successful, and the drawing force required was only 6500 kg. In this connection, a transition radius of zero is the theoretical ideal, and, in practice, the optimum radius should approach zero.

Owing to the small thickness of the material used and the insignificant elastic deformation of the components, the friction force in the cylindrical part of the die represents only a small part of the drawing force, and it is therefore assumed that the height of the cylindrical part of the die exercises only a slight influence on the maximum drawing force involved. Experiments carried out with various heights of the cylindrical part of the die have fully confirmed this assumption, most of the tests being successful, except with a height of 4 mm in the case of brass and 1 mm in the case of aluminium, when cups could be produced only from flat blanks. It is recommended that the height of the cylindrical part of the die should be at least 4 mm but should not exceed ten times the thickness of the material to be drawn.

In a final series of tests, it was established that, in deep-drawing with negative clearances, the magnitude of the tip radius of the punch has no influence on the hardness of the drawn portion of the cup or on the quality of the drawing operation and the maximum drawing force required. In the case of flat blanks, good results were obtained with all the materials investigated, using tip radii of from 0 to 10 mm and z/t values of 0·7. In the case of cup-shaped blanks of the deep-drawing steel, aluminium, and brass, satisfactory results were also obtained with tip radii of from 2 to 10 mm. In actual practice, the tip radius is generally determined by the requirements of the finished component, but it is recommended that sharp edges, i.e., using a tip radius of zero, should be avoided, and that tip radii of at least 0·5 to 0·9 mm should be employed. Furthermore, if sharp edges have to be used, the finished component should be annealed.

As a result of preliminary estimates following the introduction of deep-drawing with negative clearances into several factories, it is considered that this process permits considerable savings to be made in sheet material and reduces the number of drawing operations required by from 30 to 50%, the advantages of the process being even more pronounced in the case of components requiring very deep draws.

Improving Diamond-Wheel Performance in Electrolytic Machining

By R. R. BRANDI

From *The Tool and Manufacturing Engineer*, U.S.A.,
Vol. 46, No. 1, January 1961,
pp. 80–82, 5 illustrations.

ELECTROLYTIC machining is an electrochemical deplating process in which a low-voltage current passes through a conductive fluid flowing between the workpiece and the metal bond of a diamond wheel. As shown in Fig. 1, which illustrates the principle of electrolytic machining, deplating of the workpiece is caused by the electrolyte flowing between the negatively charged wheel and the positively charged workpiece.

The diamond particles in the wheels used for electrolytic machining do not actually cut metal, but act as insulators or spacers, maintaining the correct gap between the wheel and workpiece and preventing the conductive metal of the wheel from forming a short-circuit with the workpiece. They also serve to wipe away any oxide produced on the machined surface by the deplating action, thus exposing the surface for further machining. Diamonds are ideal for electrolytic machining, as they do not conduct electrical current and have a high resistance to wear. Because of this high wear resistance, the optimum gap between the metal wheel and workpiece (usually about 0·001 in.) can be held satisfactorily.

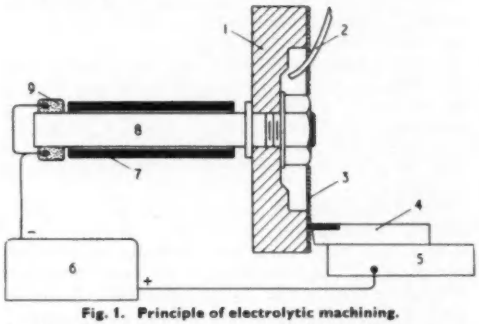


Fig. 1. Principle of electrolytic machining.

(1) Electrode wheel.
(2) Pipe for supplying electrolyte.
(3) Insulating diamond particles.
(4) Workpiece.
(5) Worktable.
(6) Electronic power supply.
(7) Insulating sleeve.
(8) Grinding-wheel spindle.
(9) Current pick-up brushes.

Electrolytic machining is being increasingly used for grinding hard materials, e.g., tungsten carbide tips for cutting tools, because there is little wheel wear and because there is no possibility of thermal damage to the workpiece. Fine finishes are produced in one operation and, considering the hardness of workpiece materials such as tungsten carbide, machining rates are relatively fast.

With regard to the selection of diamond wheels, it should be noted that the shape of the piece to be machined determines the shape and size of the diamond wheel used. It is important that the wheel be shaped to present the largest possible area to the workpiece during machining, thus deplating a large area.

The size and type of diamond grit in the wheel are also important. The grit in the wheel should be fairly uniform in size. Since the wheel does not cut, sharp cutting edges are not required. Friable diamonds that crack and splinter are, of course, undesirable from the standpoint of wheel life. The size and concentration of diamond grit in the wheel are determined by the size and contour of the workpiece. Grit size ranges from 40 to 200 mesh. In electrolytic machining, a much finer finish is achieved with any specific grit size than would be possible in conventional grinding with wheels impregnated with grit of the same size. As a result, larger, more durable grit can be utilized.

A diamond concentration of approximately 100 is recommended for wheels used in electrolytic off-hand tool grinding. This concentration of diamonds provides proper insulation and a slower rate of wheel wear, and assures even distribution of the electrolyte over the workpiece at the contact pressures of the electrolytic process. The depth of the diamond-impregnated matrix on the wheel surface is usually from $\frac{1}{32}$ to $\frac{1}{4}$ in. For off-hand grinding of carbide tools, a depth of from $\frac{1}{32}$ to $\frac{1}{16}$ in. is adequate.

The sintered metallic matrix holding the diamond particles must be a good conductor and must not be insulated from the mounting flange. The matrix must hold the diamonds securely, so that they do not dislodge, and must be of such hardness that oxides wiped off the workpiece do not become attached to the wheel surface, inhibiting current flow. It is also desirable that the matrix surface be porous, so that the volume of electrolyte around each diamond spacer is increased.

The machine-tool builder will recommend the best wheel type for a particular job when the machine is installed. If additional diamond wheels are purchased for the machine, it is advisable to request performance data on the wheels offered by the various makers. Such performance data are usually a good indication of the amount of experience the wheel maker has had in producing special wheels for electroyltic machining. This is a field in which actual production experience is helpful.

New electrolytic machining wheels must be conditioned before use to obtain optimum performance. The first step in conditioning is to mount the wheel on the machine, and adjust it so that the face of the wheel runs as nearly to perfect trueness as possible. The wheel should be within 0·001 in. of absolute trueness at all times. An out-of-true face will "bounce" and will consequently wear unevenly.

The next step in conditioning a new wheel is to establish the proper protrusion of the diamond particles from the matrix, in order to obtain the required gap. In unused diamond wheels, the metal matrix almost entirely covers the top layer of diamond particles. The overlying matrix of the wheel is removed by reversing the polarity of the wheel and worktable, and bringing a deplating shoe (a bar of copper, brass, or steel) into contact with the revolving wheel until the diamond spacers protrude and form a gap about 0·001 in. wide.

Initially, there will be some wear of any diamond particles that have sharp protruding points. When the edge has been taken off these sharp points, the rate of

(*Concluded on page 81*)

Radio Communication using Earth-Satellite Repeaters

By L. POLLACK

From *Electrical Communication*, U.S.A.,
Vol. 36, No. 3, 1960,
pp. 180–188, 6 illustrations.

IN the decade or two prior to 1956, transoceanic voice communication was carried predominantly by high-frequency radio circuits. The growth in the number of circuits and traffic during 1945 to 1956 averaged about 8% per year. Experience with cable systems offering higher quality and greater reliability has substantiated the expectation that transoceanic traffic would increase at least 10% per year if improved service were available. A report of the hearings of the Congressional Committee on Science and Astronautics states that present trans-atlantic-cable capacity will be exceeded by demands for service in 1962, and planned cable capacity will be inadequate by 1965.

Certainly, then, any new system that allows rapid expansion of toll-quality intercontinental communication deserves careful consideration. A radio relay system using man-made earth satellites offers such possibilities. In fact, such satellites provide a means whereby still-available frequencies can be used for important services for which they would not otherwise be suited.

The selection of an optimum transmission frequency for the satellite system, whether passive or active, is limited to the propagation "window" between 100 and 10,000 Mcs. Atmospheric and man-made noise decreases with increasing frequency, becoming negligible above 100 Mcs. In terms of decibels referred to 1 watt per kcs of bandwidth, cosmic noise decreases from a level of −160 dBW/kcs at 100 Mcs to less than −180 dBW/kcs at 1000 Mcs. Other effects, such as Faraday rotation of the plane of polarization and effects of nuclear explosions, become progressively less as frequency increases, and are negligible above 1000 to 2000 Mcs. At the upper bound, oxygen and water-vapour absorption increases with frequency from 0·01 dB/km at 10,000 Mcs to more than 0·1 dB/km at 20,000 Mcs.

In the passive case, the path loss L is given by

$$L = P_t/P_r = 16\lambda^2 d_1^4/A^2\eta_l^2 D^2$$

where P_r is the received power, P_t is the transmitted power, λ is the wavelength, d_1 is the geometric mean of the distance between the satellite and terminal, A is the area of the antenna and η_l is its efficiency, and D is the diameter of the satellite.

From the above, it will be noted that the transmitted power P_t is a function of the fourth power of the distance d_1, and that the path loss L decreases with increasing frequency for fixed ground-antenna and satellite size.

In the active case, the satellite-antenna gain will be limited by the area of the earth to be covered and the error tolerance of the attitude-stabilization system. The beamwidth of the satellite antenna will be fixed for a given orbit and, in this case of constant beamwidth at the satellite and fixed antenna size on the earth, the path loss L is independent of frequency and is given by

$$L = P_t/P_r = k\theta d_2^2/\eta_l A$$

where A is the area of the earth antenna, d_2 is the distance from the earth to the satellite, θ is the beamwidth of the satellite antenna, and k is a constant.

The quantity of information that can be transmitted over a communication system is proportional to bandwidth. Equipment-design considerations dictate bandwidths in the range of 0·5 to 2% of carrier frequency. For communication systems which use a modulation scheme yielding a large improvement factor, bandwidths will range from 10 to 40 Mcs. The equipment-design constraint is satisfied at 2000 to 4000 Mcs. A further factor to be considered is that the size and weight of components, particularly in the case of radio-frequency amplifiers and the antenna, decrease with increasing frequency.

The selection of an operating frequency then becomes a matter of determining the highest useful frequency between 1000 and 10,000 Mcs based on equipment availability.

Modulation Systems

The optimum type of modulation is defined as that yielding the greatest power efficiency for a given signal-to-noise ratio S/N. Since the satellite power is limited, the modulation scheme which will yield the desired channel S/N ratio, say 40 dB, with the least transmitted power is the preferred method. Consequently, a type of modulation is desirable that allows a substantial improvement of the channel signal-to-noise ratio S/N over the carrier-to-noise ratio C/N at the expense of bandwidth.

Since demodulation need not occur in the satellite, the type of modulation can be changed as desired at the earth station, if the translator or reflector is sufficiently broadband. Three principal types of modulation have been considered, these being respectively frequency division with single-sideband modulation, frequency division with frequency modulation, and pulse-code and frequency modulations.

Frequency Division with Single-Sideband Modulation

This system, designated FDM-SSB, comprises a frequency-division multiplex with amplitude-modulated subcarriers which apply single-sideband modulation to the radio-frequency carrier.

In this system, the signal-to-noise ratio S/N equals the carrier-to-noise ratio C/N, and can be expressed as

$$S/N = C/N = 10 \log (1/KT) - 10 \log b - L + 10 \log P_t$$

where b is the signal bandwidth, $K = 1{\cdot}38 \times 10^{-23}$ is Boltzman's constant, and T is the effective absolute temperature of the receiver.

Frequency Division with Frequency Modulation

This system, designated FDM-FM, is a frequency-division multiplex with amplitude-modulated subcarriers which frequency-modulate the radio-frequency carrier. A r.m.s. C/N ratio of 12 dB is the accepted threshold of a frequency-modulated system, noise improvement not being realized below this value, and

can be expressed as

$$C/N = 10 \log (1/KT) - 10 \log B - L + 10 \log Pt$$

and, with a C/N ratio of 12 dB or more, the S/N ratio is

$$S/N = (C/N) + 20 \log (\triangle f/f) + 10 \log (B/2b)$$

where B is the intermediate-frequency bandwidth, f is the highest modulating frequency, and $\triangle f$ is the peak deviation.

Pulse-Code and Frequency Modulations

This system, designated PCM-FM-FDM, consists of pulse-code modulation (time-division multiplex) with the pulse frequency-modulating the carrier, several of which can be frequency-multiplexed to obtain a larger number of channels.

In this pulse-code system, the bandwidth must first be determined. By using a 6-bit code and sampling at twice the highest audio frequency, the bit rate for each voice channel will be $6 \times 8000 = 48{,}000$ bits per second, and the video frequency will be $48{,}000/2 = 24{,}000$ cps. To transmit the video information of a multichannel system with the least power, a gaussian-shaped response is used. It can be shown that the 3-dB bandwidth of the overall system need equal only twice the video rate to obtain an acceptable interchannel crosstalk ratio, so that a radio-frequency bandwidth of twice the pulse rate will be used.

Since the pulse information frequency-modulates the radio-frequency carrier, the frequency-modulation threshold noted above must be exceeded. In addition, there is a pulse-code-modulation threshold below which the noise improvement fails. This point is reached when the pulse-signal voltage cannot be separated from noise with great certainty.

With regard to the video signal, it should be noted that an r.m.s. S/N ratio of 9 dB is an acceptable threshold value, i.e., lower than that for frequency modulation. When this threshold of 9 dB for pulse-code modulation is exceeded, the channel S/N ratio is much higher than 40 dB. The carrier power P_{tA} required in the case of pulse-code and frequency modulations, neglecting the frequency-modulation threshold, is

$$P_{tA} = -10 \log (1/KT) + 10 \log B - 20 \log (3\tfrac{1}{2} \triangle f/f) + 9 + L$$

A class of demodulation referred to as synchronous or phase-locked detection will lower the threshold by from 3 to 6 dB.

An analysis has been made on the basis of 12 voice channels, and it is assumed that the satellite receiver and transmitter must be capable of handling the total number of channels. Fig. 1 shows the r.m.s. signal-to-noise ratio S/N of the channel as a function of the received signal or carrier power in decibels referred to 1 W for the three modulation systems discussed, and is based on a system providing 12 voice channels, each of 3-kcs bandwidth, a receiver noise figure of 1 dB, and an antenna temperature of 40°K. Fig. 1 shows the advantage of the system using pulse-code and frequency modulations with frequency-division multiplexing (PCM-FM-FDM). Thus, in the case of the system using frequency divivision with single-sideband modulation (FDM-SSB), an S/N ratio of 40 dB is obtained with a carrier power of about −118 dB referred to 1 W, while the system using frequency division with frequency modulation (FDM-FM), assumed in this case to have a peak modulation index $\triangle\theta$ of 4, requires 9 dB less power. The PCM-FM-FDM system offers considerable power reduction, the received signal power with an S/N ratio of 40 dB being −148 dBW, i.e., an improvement of 30 dB over the FDM-SSB system.

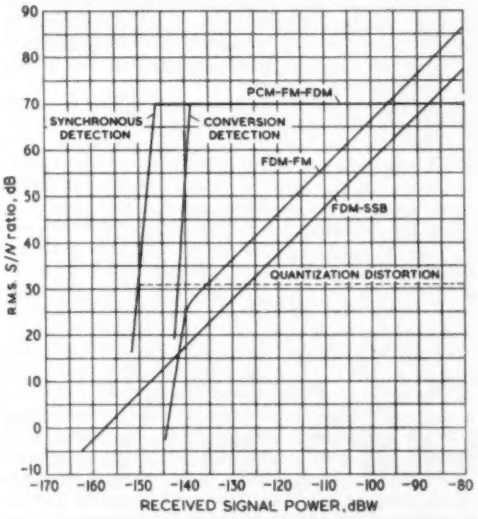


Fig. 1. Signal-to-noise ratio S/N as a function of received signal power in decibels referred to 1 W for modulation systems providing 12 voice channels, each of 3-kcs bandwidth.

Classification of Satellite Repeaters

Orbital radio relays can be classified into two broad groups, depending on whether they are passive or active repeaters. In addition, they can be further categorized as near-orbit and 24-hour-orbit satellites. In this connection, near orbits are considered as those with a period of from 1 to 3 hr at an altitude between 800 and 4800 km, whereas the 24-hour-orbit satellite rotates in synchronism with the rotation of the earth when it is placed in an equatorial plane at an altitude of just under 35,900 km.

Passive Satellites

The parameters of a passive-satellite system have been thoroughly analysed by Pierce and Kompfner*, who have shown that transatlantic communication could be established more efficiently by a number of satellites in a polar orbit at an altitude of 4800 km. These satellites, comprising aluminized plastic balloons of spherical shape, would assume random positions in their orbits. As the altitude of an orbit increases, the number of satellites required to maintain a specified continuity of service decreases, while the transmitter power required increases with orbit altitude. In the case of an altitude of 4800 km and a service interruption of less than 0·1%, thirty satellites would be required.

Fig. 2 shows the transmitter power per kcs of bandwidth as a function of the diameter of the ground antenna required with passive balloon-type reflectors of 100 and 1000 ft diameter and transmission frequencies of 2000 and 8000 Mcs. The curves are based on a receiver temperature of 75°K and an antenna temperature of 20°K and assume a free-space loss of 2×177 dB, a receiver KTB-value of 208·8 dB referred to 1 W/cps, and

* R. Pierce and R. Kompfner: "Transoceanic Communication by means of Satellites"; *Proc. I.R.E.*, Vol 47, March 1959, pp. 372-380.

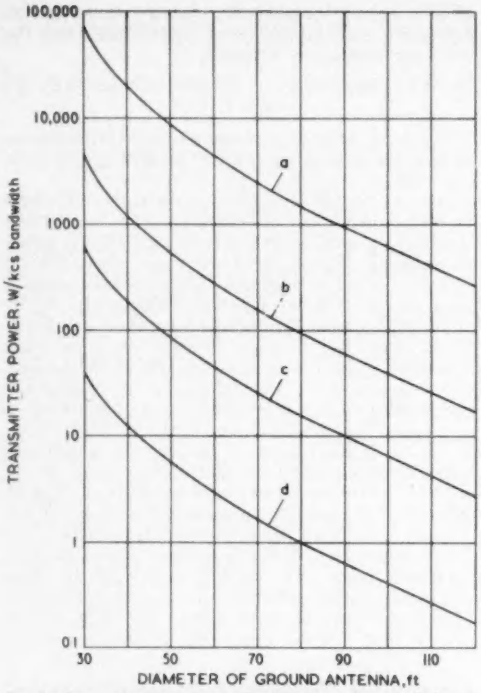


Fig. 2. Transmitter power required per kcs of bandwidth as a function of the diameter of the ground antenna for passive reflectors in a 4800-km orbit (a) of 100-ft diameter operating at 2000 Mcs, (b) of 100-ft diameter at 8000 Mcs, (c) of 1000-ft diameter at 2000 Mcs, and (d) of 1000 ft diameter at 8000 Mcs.

a C/N ratio of 15 dB. It should be noted that the receiver noise figure is somewhat more pessimistic than that assumed by Pierce and that the C/N ratio is based on wide-band modulation techniques.

It will be seen from Fig. 2 that, using a reflector of 100 ft diameter, an operating frequency of 2000 Mcs, and an earth antenna of 120 ft diameter, a power of about 130 W per kcs of radio-frequency bandwidth is necessary. With wide-band modulation systems, such as pulse-code modulation, an information bandwidth of 4 Mcs can be transmitted with a radio-frequency bandwidth of 24 Mcs, yielding an S/N ratio of better than 40 dB. Such a system would require an increase in the earth-transmitter power of 34 dB, i.e., to approximately 3 MW—an impracticable level at present. If, however, the operating frequency is raised by a factor of 4 to 8000 Mcs, the transmitter power will be reduced by a factor of 16, provided that antenna efficiency can be maintained and that atmospheric absorption is neglected.

To sum up, it may be said that passive systems are characterized by a large number of satellites, large earth antennae, and high transmitter power to cover a relatively small area of the earth. They may, however, play an important interim role in transoceanic communications pending the development of reliable electronic systems and the high-powered rocket boosters that will be required to launch active satellites.

Active Satellites

A larger satellite reflector would reduce the power required on earth, but a controlled propulsion mechanism for maintaining optimum position and attitude would be needed. If such a complication is resorted to in spacecraft, it is only a simple additional step to incorporate a transponder and thus evolve an active repeater.

Near-orbit active satellites are already under development for military purposes and, in addition to world-wide high-speed capabilities, their communication facilities are designed to provide continuity of service under conditions of jamming and interference. One such project is concerned with a satellite in an orbit between 960 and 1125 km approximately, activated as it comes into view of a ground station that has traffic for another ground station. Teleprinter signals, previously stored on magnetic tape, are transmitted at a high speed to the satellite, which then stores the message and retransmits it at high speed when it is in view of the addressed station and when commanded to do so by a coded signal. During reception of stored messages from the satellite, the earth station can also transmit traffic for other stations to the satellite on a different frequency. By transmitting at a high information rate during the 4 to 5 min in which the satellite is reliably in view of the earth station, it is possible to transmit the traffic of twenty teleprinter channels operating continuously at a rate of 100 words per minute. For an active operating time of 3 min when the satellite is within range of the earth station on each orbit, the traffic-handling capacity would be 15,000,000 bits, i.e., the capacity of each satellite recorder, corresponding to 428,000 words per satellite pass per station. With a ground station operating in a latitude of, say, 20°N, and a satellite at an altitude of about 960 km orbiting in 110 min, there would therefore be seven useful orbits per day, i.e. nearly 3,000,000 words per day handled by such an earth station.

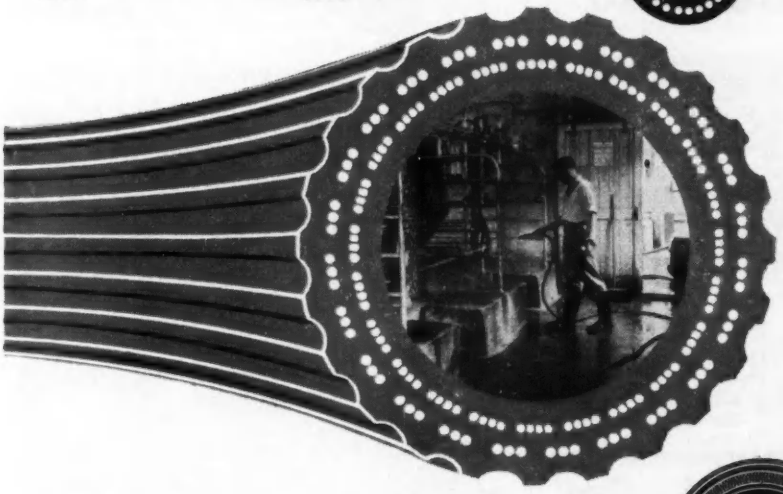
As in the case of passive satellites, a large number of near-orbit active satellites and steerable ground antennae must be used for continuous coverage. It should also be appreciated that the altitude of an attitude-controlled near-orbit satellite will limit the antenna beamwidth of the satellite. The path loss, the gain of the satellite antenna, and the coverage on earth decrease with altitude, so that, if the satellite is moved from a 4800-km orbit to a synchronous orbit at 35,900 km and if an antenna beam tangential to the surface of the earth is used, only 5 dB more power is required.

In the case of active satellites with a 24-hr orbit, three satellites in an equatorial orbit of approximately 35,900 km can cover about 98% of the surface of the earth. For world-wide communication systems, this would appear very attractive, though the most severe limitations are the power output of the satellite transmitter and its life.

At the synchronous-orbit altitude, the beamwidth of the satellite antenna for hemispherical coverage is 18°. Allowing a margin for positional error of ±4°, a 25° beamwidth can be used, yielding a gain of 16 dB at 2000 Mcs. With 60-ft paraboloidal reflectors on the earth and a receiver noise figure of 1 dB, a satellite transmitter rated at 2 W can handle 96 voice channels. It should be noted that there is a large difference in peak power output among the various modulation systems previously compared, and the peak power demand can be troublesome with an active-satellite transmitter, particularly if a klystron or travelling-wave tube is used in the output stage.

Finally, it may be said that an active system, capable of handling as many as 1000 voice channels, can be implemented within two years, and that these satellites can compete economically and technically with other reliable systems, such as submarine cables.

YOU NAME THE JOB WE HAVE THE HOSE



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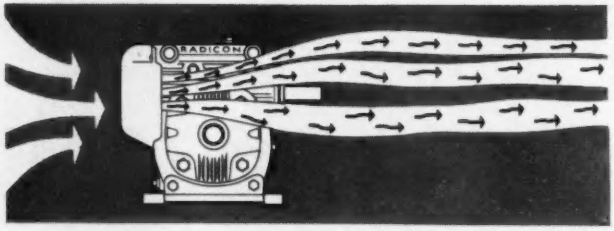

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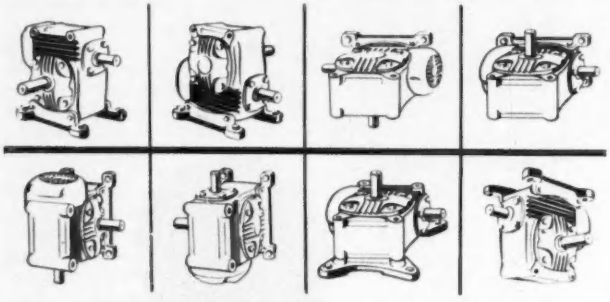

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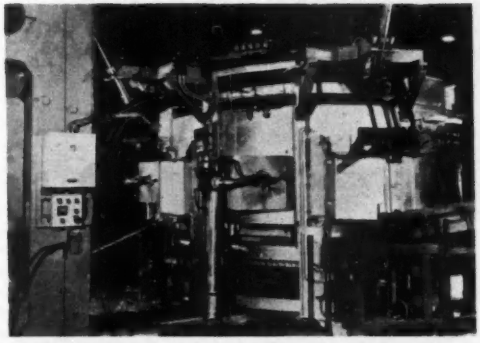
British Industrial Developments

Automatic Loading and Unloading Equipment for a Rotary-Hearth Forging Furnace

Automatic loading and unloading equipment for a rotary-hearth furnace which preheats steel billets prior to forging has been designed and constructed by The Hymatic Engineering Co. Ltd., of Redditch, Worcs. This equipment, which is operated by compressed air, has been installed on a furnace manufactured by Franklins, of Birmingham, and is being operated at the works of Smiths Stamping Ltd., of Coventry.

The oil-fired furnace has been designed to operate at temperatures up to 1300°C. The oil burners are automatically controlled from billet temperature and fire tangentially round the working space of the furnace, thus requiring the unloading arm in particular to work directly in the path of one of the main burners. The hearth of the furnace is automatically indexed at a predetermined distance by a pneumatically operated ratchet-and-pawl mechanism operated by signals from the Hymatic equipment. The jaws of the equipment will handle billets from 3½ to 6 in. square, up to 18 in. in length, and weighing from 30 to 104 lb. The throughput rate of the furnace is controlled at 35 cwt per hour. The doors of the furnace, which are pneumatically operated, open downwards, leaving the area above and around the furnace clear for the loading and unloading equipment.



The Hymatic equipment, which takes the form of two mechanical arms hinged at their upper points, is attached to vertical buck-stays positioned around the furnace, which is 15 ft in diameter. The loading and unloading equipment is synchronized with the furnace doors, and the mechanical movement of the doors is taken as the signal for the operation of the pneumatic equipment. Although the furnace temperature is very high, it does not interfere with the operation of the pneumatic equipment or the air rams fitted to the outside, as the furnace is encased in a firebrick outer wall, 18 in. in thickness, and the outside temperature is not abnormal.

The cold forging billets are transferred from the loading point onto the automatic billet-lift by a gravity-type conveyor. When a billet has been transferred onto the loading device, it automatically rises, inserting the billet into the gripper jaws of the loading device. When the loading device has reached the top of the lift, a limit-switch is operated, closing the jaws gripping the billet, initiating the return of the loading device to its normal down position, and leaving the billet ready for loading into the furnace. Working in conjunction with the billet-lift is a device which meters the billets one at a time onto the lift and ensures that a billet is not transferred to the lift when it is in a raised position.

On receiving a signal from the timer controlling the rate of operation of the furnace, the furnace-door control equipment operates, opening the doors on the loading and unloading apertures of the furnace. As soon as these furnace doors are opened, the loading and unloading devices advance into the furnace, the loading device depositing the billet onto the furnace hearth and the unloading device gripping the heated billet. The devices then withdraw to their out positions. On this withdrawal stroke the furnace doors reclose, and the hearth of the furnace is indexed one stroke. When the two devices are fully withdrawn, the jaws of the unloading device open, allowing the hot billet to fall onto a discharge chute for transfer to the hammer or press, as shown in the illustration, in which can be seen the billet in-feed conveyor, the discharge transfer chute, and the power press. Fitted in a control cabinet close to the furnace is all the electrical equipment necessary for the automatic cycling of the furnace loading and unloading devices.

Automatic Transformer-Core Plate-Cutting Machine

Designed and developed by Ferranti and manufactured to their instructions by A. Kinghorn & Co. Ltd., of Todmorden, Humphries and Sons Ltd., of Poole, and The Norbury Engineering Co. Ltd., of Hyde, a new and fully automatic transformer-core plate-cutting machine has recently been installed in the Transformer Department of Ferranti, Ltd., of Hollinwood, Lancs. The plant has been in production since July 1960, and is stated to have achieved its original objectives of producing core laminations to a higher degree of accuracy than has hitherto been possible, resulting in an increase in core efficiency. It has also overcome handling difficulties, with a consequent increase in productivity.

The machine, which is equipped with safety devices at all stages of operation, combines in one operation the piercing of all holes or slots and the cutting of two plates per cycle of the machine. Provision is also made for grinding edge burrs, if necessary. All dimensions are related to the theoretical centre-line of the strip of material, i.e., the centre-line of the core. This has the advantage of dividing possible inaccuracies in the width dimensions equally to both sides of the plate, and not to one side only, as in the case of guillotine or press production, where all measurements are made from one datum edge of the material. The possibility of variations in length dimensions occurring through human error in the case of guillotine and press production have been eliminated by cutting both ends of each plate and punching all holes and slots in one operation of the machine while the strip of material is in tension.

The bed of the press is 30 ft in length and 56 in. in

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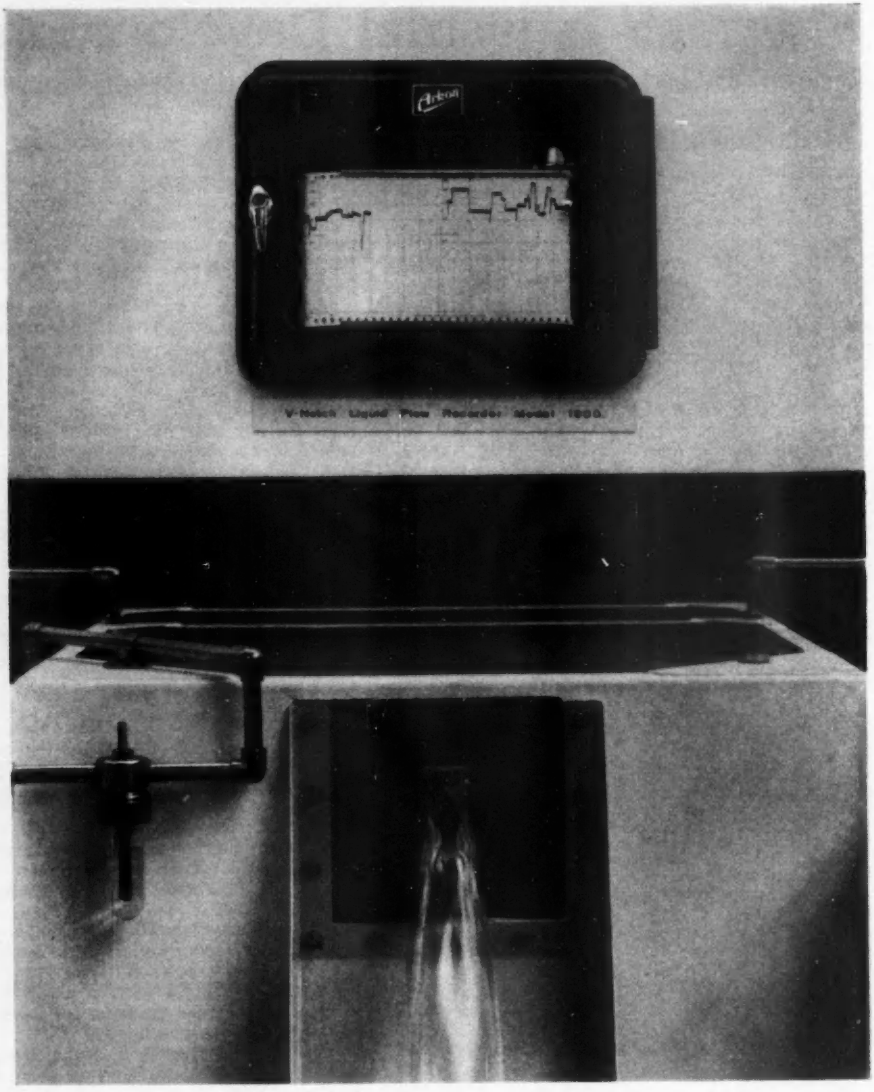

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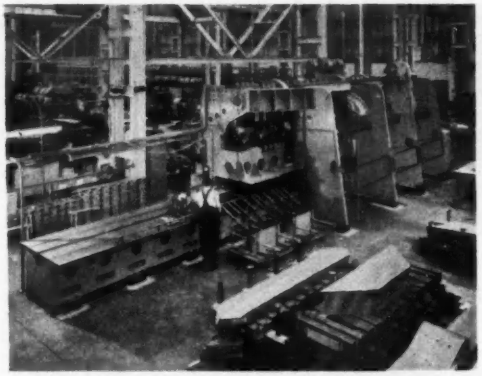
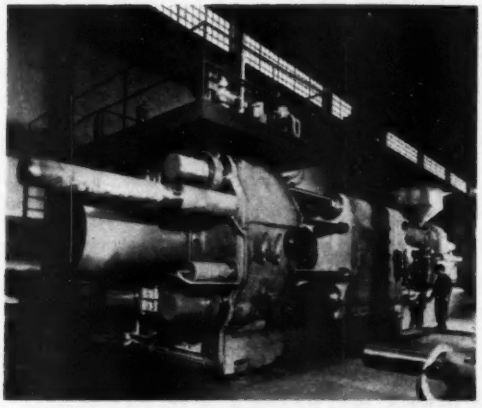


width. The machine is fed automatically to cut laminations two at a time, each 15 ft in length and 36 in. in width, a special facility being incorporated for cutting laminations up to 47 in. in width. The illustration shows the machine with the material in tension just prior to press operation and ejection. The second plate is ejected on the opposite side of the machine.

Large Injection-Moulding Machines

As announced by Baker Perkins Granbull Ltd., of Kingston-on-Thames, through whom Triulzi machines are available in the U.K. and the Commonwealth, the largest and most powerful injection-moulding machines in the world, with an injection capacity of 425 oz and a locking pressure of about 2250 tons, have been produced by Triulzi, of Milan, Italy. Stated to be ideal for producing household articles, the first three units of this type have been ordered by a German firm for the production of refrigerator shells at a rate of one shell every two minutes.

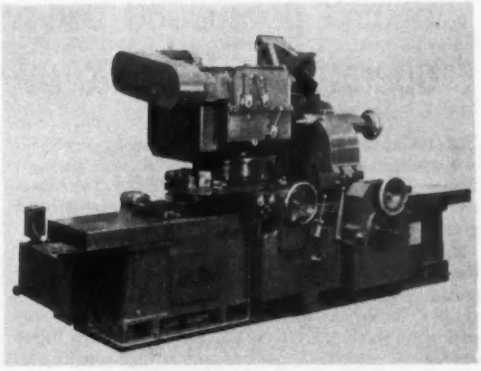
The machine is designed for an automatic cycle, but every movement can be controlled separately by means of push-buttons. The injection force can be adjusted up to a maximum of 220 tons and, with a standard injection plunger, it is possible to obtain up to 22,000 psi. With this pressure and with the very high injection-plunger speeds obtainable, it is possible to process any thermoplastic material and to obtain thin-walled mouldings.



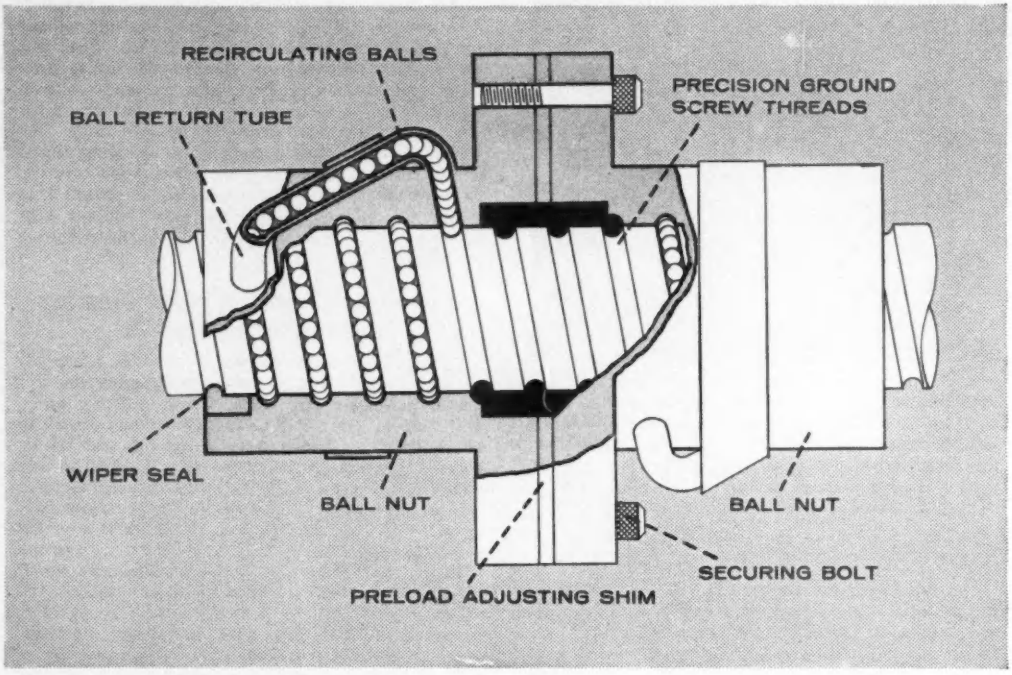
The body of the machine is cast in steel, with rolled-steel sections in the bedplate. The rams and tie-bars are ground and are hard chrome-plated. Steel and special materials have been used for the sliding parts and components under stress. The hydraulics, valves, distributors, and servo-controls are located on an accessible platform fitted over the reaction head. All electrical and electronic equipment, including timers for setting times and automatic temperature controls, are located in a special sheet-sealed box to protect them from dust and temperature variations, and are kept separate from the machine, so that no possible vibration can affect them.

Universal Grinding Machines for Extra-Heavy Duties

Keighley Grinders (Machine Tools) Ltd., a member of the Newall Group, announce the development of a fully universal grinding machine for extra-heavy duties, with a 37-in. swing and a capacity between centres to suit requirements in the range between 24 and 120 in. The 24-in. model illustrated has been designed to user specification for grinding large die-blocks weighing up to 1500 lb and extending 11 in. from the workhead faceplate. Massively proportioned, the machine base has X-section ribbing and extra-wide table ways. The top table platen has a width of 11 in., the table power traverse is steplessly variable in the range provided, and adjustable dwell control is incorporated. To facilitate precise manual control of table movement, the handwheel mechanism is mounted in anti-friction bearings, an interlock preventing power traverse when the handwheel mechanism is engaged.



The wheelhead is mounted on a circular base, which is, in turn, supported on an underslide to provide facilities for wheel feed to be applied at any angle. The lower table is equipped with a worm-gear mechanism for ease and accuracy of indexing. The upper turntable is floated on an oil film during adjustment to the angular position, the upper surface of this slide being tee-slotted in order to locate the wheelhead positively when steep angles have to be ground. A useful feature of the wheelhead is the provision of a separate rapid power traverse which can be advantageously employed when positioning for grinding a new diameter. Application of the lever controlling this function automatically disengages the dead-stop, eliminating any possibility of damage, while the limit-switches incorporated prevent over-run.



Beaver pre-loaded ball screws, up to 95% efficient, operate at −52°C to over 400°C with no backlash

Bristol Siddeley Engines Limited produce Beaver* pre-loaded ball screws. These ball screws achieve a minimum efficiency of 90% and they can operate within a temperature range of—52°C to 400°C without lubrication, and up to 170°C when lubricated.

Machined and ground to the highest standards of precision engineering Beaver pre-loaded ball screws greatly increase transmission efficiency. They reduce the power required for actuation by as much as 80%, when converting rotary drive into linear output or force input into torque output. By eliminating backlash, with pre-loading, they give precise control over very small increments of motion and a high response frequency. And when compared to conventional screw mechanisms, they provide a predictable operating life which is much longer, require much less maintenance and give more trouble-free operation.

Basic design application analysis

Bristol Siddeley engineers make an exhaustive analysis of each specification. And each unit is specially designed for its particular application. Beaver ball screws are made automatically reversible or with controlled "no-back," with multiple or single circuits. Beaver pre-loaded ball screws have been proved as the most efficient method of converting rotary into linear thrust in over 2,700 engineering applications in many branches of industry. They have been designed already with rated operating load capacities of 370,000 lb (825,000 lb maximum static load) but the maximum potential operating load is, in most cases, limited only by the requirement.

Bristol Siddeley Beaver ball splines have been developed to eliminate the disadvantages of conventional splines. The designs are very effective in minimising friction, particularly when high torsional and bending loads are imposed during linear movement.

**Complete technical and manufacturing co-operation with Beaver Precision Products Inc, Detroit.*

For further information please write to:
J. B. STARKY, SALES MANAGER (BALL SCREWS AND SPLINES), BRISTOL SIDDELEY ENGINES LIMITED
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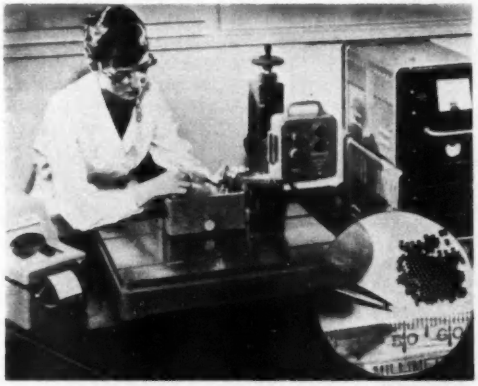
BRISTOL SIDDELEY ENGINES LIMITED

The wheelhead in-feed, applied at every reversal of the table, is steplessly variable between 0·0002 and 0·0020 in. The heavy-duty live- and dead-centre workhead, equipped with a gearbox to provide twelve work speeds in the range between 5 and 100 rpm, is mounted on a large-diameter turntable and can be swivelled to any desired angle. A flanged steel spindle, 6 in. in diameter, runs in high-precision taper roller bearings, which are grease-packed to minimize maintenance requirements.

Attachment for Measuring the Surface Finish of Small Balls

Capable of enabling the surface finish of a ball of 1 mm diameter to be measured and recorded accurately in half-millionths of an inch, a new small-ball surface-measuring attachment has been developed by the Taylor, Taylor & Hobson Division of Rank Precision Industries Ltd. for use with the "Talysurf" Model 3 surface-measuring instrument.



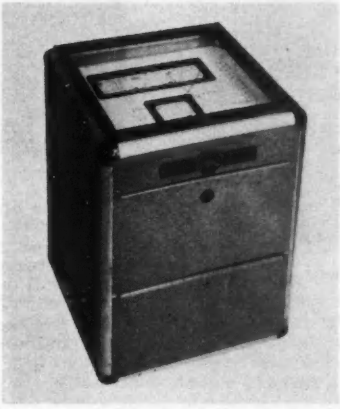
Fundamentally designed with a view to production testing and to cater to the demand for measuring high-speed precision bearings, the attachment, which is easily and quickly set up, consists of a stationary pick-up unit, in which a stylus is mounted underneath a conical seating. The ball to be tested is placed in the seating, where it is then rotated by a friction drive, controlled from the standard "Talysurf" gearbox. The ball is given the same surface velocity as that normally applied to the traverse of the conventional "Talysurf" pick-up, permitting both graphs and average readings to be obtained from the standard instrument. The range of balls catered for is from 1 mm to 1 in. diameter, and graph readings are recorded with magnifications up to ×50,000, 0·1 in. on the paper representing 0·000002 in.

Transportable Equipment for Drying Electrical Circuits

Manufactured in Norway by Marinens Hovedverft, Horten, and of particular interest in the marine-engineering field, transportable equipment for the detection *in situ* of faulty insulation in electrical apparatus and the removal of moisture causing failure is now available in the U.K. from the Marine Department of the A.E.I. Telecommunications Division, of Woolwich, London, S.E.18, who have the world marketing rights, with the exception of Scandinavia, France, Holland, Germany, and the U.S.S.R.

The intrument, designated E.A.F. equipment, is essentially a low-potential source of supply of drying current which is passed through the circuit whose insulation has been found to be faulty. The unit is fitted with a voltmeter and ammeter for indicating the voltage applied and the current flowing during the drying-out process, a megohmeter for the continuous monitoring of the insulation resistance, a resistance thermometer for indicating the temperature of the conductor during drying, and a thermostat for controlling the drying temperature to avoid overheating of the conductor and insulation. A graph on the top plate of the instrument shows the relationship between the current-carrying capacity of the conductor being treated, the heating effect of the drying current, and the life of the cable under various drying conditions, these curves applying only to long-term overloading of the conductor, as short-term overloading has no serious effect. The equipment operates from a 220-V, 50/60-cps a.c. supply, a converter being required for ships with d.c. mains. Output terminals are provided to cater for five different cable sizes, with an additional terminal for larger cable sizes, in which case the thermostatic control does not operate and the ammeter and voltmeter are used as checks. Damage to the cable through overheating cannot result, and the equipment itself is protected against overloading by automatic fuses. A maximum output of 2 kVA is available.

To dry out a faulty cable, the remote end is first short-circuited. Where there are more than two cores, it may be enough to use only two to carry the drying current. A multi-core cable can be completely short-circuited at the remote end with the cores separated into two groups at the other end and connected to the equipment as a two-conductor cable. Testing and drying-out of motors can be effected by testing through the supply circuit or by connecting directly into the terminal board of the motor, heating of the motor in this case being largely achieved by utilizing the iron losses.



The correct drying current is chosen for a particular size of cable from a table on top of the equipment, and the voltage required to supply this current (which will vary according to the overall length of cable to be treated) found by experiment on the output terminals. During the drying period, a test-button can be depressed to switch off the drying current and to switch in the megohmeter to show the insulation resistance of the cable while it is warm, so that any latent insulation

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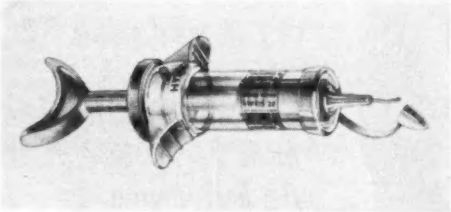
faults are more readily detected. As the temperature of the cable rises, any moisture present moves towards the ends of the cable, where the concentration rises rapidly; however, because the supply voltage is low, there is no flash-over. As the temperature of the cable rises above the ambient level, the moisture is rapidly evaporated. Drying out of the cable usually takes very little time. Further penetration of moisture can then be avoided by finishing the ends of the cable with insulating varnish and tape.

Micrometer-Controlled Syringe for Feeding Diamond Lapping Compounds

In many grinding and lapping operations, use is made of compounds containing diamond particles suspended in a variety of special pastes. As minute quantities of these compounds are generally needed for such operations, and as they are extremely costly (up to £120 per ounce), it is obvious that substantial savings can result if they are accurately dispensed. It is for this reason that a new micrometer-controlled syringe, designated the "Hyplicator", has been introduced by Engis Limited, of Maidstone, for the accurate metering of their "Hyprez" diamond compounds for grinding and lapping operations.



Because, in some cases, surfaces brought to a high finish can be damaged by corrosion products, especially crystalline copper sulphate, resulting from the use of an applicator gun made of metal, the body of the "Hyplicator" is made of moulded nylon, with a threaded nylon shaft engaging with a knurled micrometer screw, also made of nylon, in the top of the barrel. The shaft is connected to a neoprene plunger, the base of which has a greater radius of curvature than that of the nozzle cup into which it descends, ensuring that every vestige of the compound is forced into the centre of the cup and down the nozzle as the syringe empties. The entire nozzle fitting can then be removed and attached to a freshly loaded syringe, so that none of the compound is wasted.

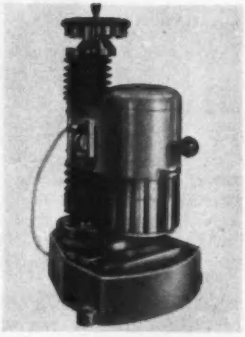
Special-Purpose Palladium-Containing and other Brazing Alloys

A range of special-purpose brazing alloys available from the Baker Platium Division of Engelhard Industries Ltd., of London, W.C.1, is stated to open up a much wider field of brazing techniques, so much so that many operations which have hitherto entailed welding operations or mechanical assembly now lend themselves to brazing, with a resulting economy in time and equipment. For maximum strength of the brazed assemblies, lap joints are normally recommended, and correctly designed joints will possess a strength which is greater than that of the parent metal. In fact, the choice of a brazing alloy of appropriate melting range can lead to assemblies with greater strength than that obtained by welding, as the deleterious effects on the structure of the parent metal, arising from overheating during the welding cycle, can be avoided.

The range of special-purpose brazing alloys available includes certain of the established silver-copper, gold-copper, and gold-nickel alloys, also the recently developed palladium-containing alloys, i.e., silver-copper-palladium, silver-palladium-manganese, copper-palladium-nickel-manganese, palladium-nickel, and nickel-manganese-palladium alloys. In general, all these alloys offer important advantages over conventional brazing materials in respect of their strength at high temperatures, their low vapour pressure, and the fact that they enable certain materials which cannot be brazed with conventional alloys to be joined satisfactorily. Additional advantages offered by the palladium-containing alloys include the reduction of erosion of the parent metals to a minimum, enabling thin sections to be readily joined, and the ability to join metallized ceramics directly to low-expansion alloys without the need for nickel-plating the ceramic.

Small Bench-Type Precision Surface Grinder

A small hand-operated bench-type precision surface grinder, designated the "Precisa FS 2", announced by The H. G. Stevens Co. Ltd., of London, N.W.2, is capable of dealing with diameters up to 7¾ in. and with rectangular areas of up to 6 × 12 in. and 4 × 16 in. Occupying little more space than a fly press or bench drill, the machine is suitable for use in maintenance departments and mobile workshops, in tool rooms, either by itself or to supplement existing grinding capacity, and for production work, particularly for the batch or flow production of components requiring the removal of only small amounts of metal. The 3-hp, 2800-rpm motor and the grinding spindle are dynamically balanced as a unit and, in conjunction with the rigid construction of the machine as a whole, ensure a first-class finish (flat or hollow-ground, as desired).



The vertical feed scale is optically magnified and is calibrated in steps of 0·00025 in. All bearings are carefully sealed and the feed spindle is completely protected by leather bellows. As a result, it is claimed that the machine has an accuracy of better than 0·00025 in., which should be retained throughout its service life. The standard cup wheel supplied for a normal fine finish has a diameter of 7¾ in. but, if required, can be replaced by a special segmental head and wheel for grinding at twice the normal grinding speed. Other accessories include special grinding wheels for glass, ceramics, etc., a pump-driven wet-grinding set, a choice of magnetic chucks, including an electromagnetic type with a built-in demagnetizing device, and a quick-action diamond-dressing attachment which makes it unnecessary to alter the machine setting when dressing the grinding wheel.

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ADDITIONAL ABSTRACTS

Cylinder-Pressure Variations in Petrol Engines

By J. P. SOLTAU

From a paper presented at a meeting of *The Institution of Mechanical Engineers*, London, December 13, 1960, 16 pages, 12 illustrations.

FOR some time past, it has been taken for granted that a spark-ignited petrol engine produces cylinder-pressure values which are not reproduced identically during each individual cycle. In some quarters, this cyclic variation has been blamed for engine roughness and for high fuel consumption, compared with a compression-ignition unit. It has also been said that, if all cycles could be made equal to the highest pressure ones, a gain in power of 10% could be realized, without affecting the petrol intake.

If actually an increase of power of as much as 10%, with a corresponding decrease in specific fuel consumption, could be obtained, these cycle pressure fluctuations would indeed be a serious matter and would warrant a thorough investigation. It was therefore decided to study the problem employing existing equipment, i.e., a single-cylinder Renault 500-cc engine, capable of being run at a speed of 4500 rpm and with variable compression ratios between 4·5 : 1 and 13 : 1. The tests provided some valuable information, and showed that the possible gain in output by bringing all cycles up to the level of the most efficient is of the order of 2% with a slightly richer than stoichiometric air/fuel ratio, but larger improvements of the order of 10% or more could be obtained with weaker mixtures.

This paper describes the detailed research programme involved, in which every working variable was altered in turn, and its effect on combustion observed on an electronic engine indicator. The development of the cylinder pressure over a large number of cycles was recorded at each setting with the aid of an oscillograph camera. For more detailed observations, the photographed traces were replotted on a volume scale, and individual $P - V$ diagrams were studied and in some cases drawn as $\log P - \log V$ graphs. The experiment showed that the fluctuations in peak pressures and i.m.e.p. were caused by differences in the heat-release rate from cycle to cycle. All hydrocarbon fuels exhibit similar variations, but town gas, with its more rapid burning, produces steadier pressure development. The air/fuel ratio of the mixture is the main factor which influences the magnitude of the maximum pressure variations, from cycle to cycle. The steadier mixture ratio is in the order of 13, and on either side of this the fluctuations increase rapidly, especially on the weak end. Using several simultaneous ignition sources, it is possible to decrease the individual flame front path and therefore to increase the resulting combustion speed, reducing the fluctuations.

The Case for Standardizing Airport Apron-Outlet Distribution Systems at 1000 V, 400 cps

By J. B. CHAPMAN

From *Power Apparatus and Systems* (*A.I.E.E.*), U.S.A., No. 50, October 1960, pp. 782–788, 8 illustrations.

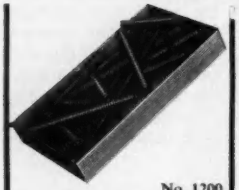
ONE of the desirable features of the jet-age airport is the use of fixed outlets, adjacent to the parking positions of aircraft on the apron, from which electric power is supplied to aircraft. Such an outlet was a rare occurrence in the past; in fact, the common practice was, and still is at most airports, for each airline to supply power from a mobile, engine-driven generator. Nevertheless, the operational advantages of such apron outlets are obvious.

The design of a system to supply electric power to these apron outlets is a problem which has few precedents and is a subject on which there is little available literature. The purpose of this paper is therefore to investigate the various electric systems available, to reach a conclusion as to which is best suited for this application, and to explore the possibilities of standardizing apron outlet distribution systems.

In considering apron-outlet distribution systems, comparisons are made between a 115/200-V, 400-cps system, a 380-V, 50-cps system, and a 1000-V, 400-cps system. The 115/200-V, 400-cps system comprises a 50- or 60-cps motor driving a 115/200-V, 400-cps generator located in the terminal building, power being delivered to the apron outlets at generator voltage. In the 380-V, 50-cps system, this current is distributed to each apron outlet, and a mobile motor-generator set or rectifier, adjacent to the aircraft and supplied from the outlet, converts this terminal distribution voltage to the type of system required by the aircraft. In the 1000-V, 400-cps system, a 50- or 60-cps motor would drive a 1000-V, 400-cps generator located in the terminal building, power being distributed to the apron outlets at generator voltage. A 1000-115/200-V portable transformer, or a portable transformer/rectifier, placed adjacent to the aircraft, would then be used to supply the aircraft with the required type of system.

In general, it would appear that the 1000-V, 400-cps system has much to recommend it. Naturally, the criterion of any standard is that it should be universally applicable. If an airport were to serve aircraft with d.c. systems only, there would be no need for a 1000-V, 400-cps system. However, it is expected that only major airports with heavy traffic will install apron outlets, and that a good percentage of the aircraft they will accommodate will have a.c. systems. At such airports, the determination of which system is the most economical would depend primarily upon the value of the peak demand of the system, which in turn would be dependent on the number of large turbojet aircraft with a.c. systems. It cannot be expected that the 1000-V, 400-cps system will be a panacea, but it is envisaged that it would be technically and economically preferable in the majority of cases, and very possibly a necessity when supersonic commercial aircraft are a reality.

EXPERIMENTAL SPRINGS?



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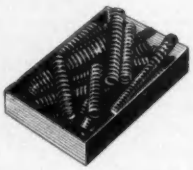

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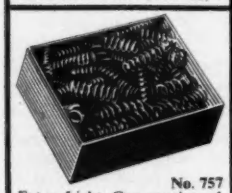

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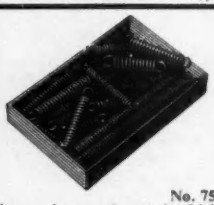

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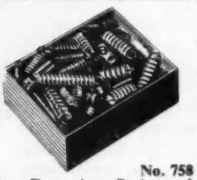

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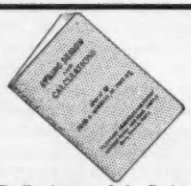

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Volatilization Phenomena in High-Temperature Brazing Filler Alloys

By W. LEHRER and H. SCHWARTZBART

From *Welding Journal*, U.S.A.,
Vol. 39, No. 10, October 1960,
pp. 449s-461s, 5 illustrations.

THE objective of the programme described in this paper was the development of oxidation-resistant brazing filler alloys containing liquidus temperature depressants which can be volatilized during vacuum brazing, bearing in mind that the removal of any temperature depressant after flow should result in a more suitable high-temperature filler alloy from the standpoint of high-temperature strength. Furthermore, it is clearly desirable to have an alloy which can be applied at a relatively low brazing temperature, and subsequently have a much greater remelt temperature.

As described in this paper, experimental brazing filler alloys of this type have been developed. The mechanisms by which remelt temperature is increased have been studied for a range of alloys containing nickel, chromium, germanium, indium, iron, lithium, and phosphorus. The two main mechanisms are dissolution of the base metal in the filler metal, with diffusion of constituents of the filler metal into the base metal, and volatilization of the filler-metal constituents.

It has been shown theoretically and experimentally that, for remelt temperature to increase, there must be solid solubility of the diffusing or volatile element in the filler alloy. Although compositional changes may result from either mechanism, a remelt-temperature change does not necessarily occur. The degree to which a compositional change affects remelt temperature is proportional to the solid solubility.

In this programme, vacuum-pumping was the most efficient vapour-removal method, among several discussed and investigated. Furthermore, under vacuum, the surface-area-to-volume ratio of the filler alloy becomes less rate-controlling as a result of boiling. Boiling, however, causes porosity in the joint.

Of the alloys investigated, one containing 61% nickel and 39% indium exhibited the highest remelt-temperature rise from volatilization alone, whereas an alloy containing 94% nickel and 6% phosphorus responded only to dissolution and diffusion to exhibit the highest rise in remelt temperature due to this mechanism. Ni-Cr-In-Ge alloys exhibited a substantial rise in remelt temperature as the result of the operation of both mechanisms. This alloy and the binary Ni-In alloy can be considered practical alloys for high-temperature use.

A direct effect of metallic vapours on wetting and flow of the filler alloy was observed and is discussed with respect to their influence on surface-tension relationships. It has been shown that, in the presence of metal vapours, discoloration of the base metal, wetting, flow, and skull formation of the filler alloy are functions of the rate and quantity of metal-vapour removal.

An Investigation into Tunnel-Burner Noise

By J. K. KILHAM, E. G. JACKSON, and T. J. B. SMITH

From a paper presented at a meeting of
The Institution of Gas Engineers, London,
November 15,1960, 13 pages, 18 illustrations.

A REVIEW of the literature on the mechanism of noise production in combustion systems indicates that, in the case of tunnel burners, the oscillations are governed by the Rayleigh criterion, coupled with the possibility of standing waves in the mixture supply pipework. In order to investigate this hypothesis, a series of simplified single-port tunnel burners, as described in this paper, was constructed. The perforated back-plate type of tunnel burner was chosen for full-scale investigation, since it is notoriously prone to noisy combustion. The effects of varying several parameters are presented in the form of combustion-stability diagrams, which clearly indicate the influence on noise production of tunnel length and back-plate thickness.

The "screech" of tunnel burners is considered to be due to a form of organ-pipe resonance. The presence of the flame, acting as an energy source to drive standing waves, suggests that Rayleigh's criterion should be applicable. The results obtained with the model burners seem to confirm this theory and also indicate the importance of acoustical feedback in the upstream direction. It must be pointed out, however, that the apparatus used represents a highly idealized system, since the upstream acoustic termination was precisely fixed. With more practical burners, the effect of injectors, manifold, etc., on the acoustic feedback is not yet known and should certainly repay further study.

The results seem to indicate that a correctly designed, perforated back-plate burner is slightly quieter than an equivalent single-port type. The single-port burner had a turndown ratio of approximately 10 : 1 at stoichiometric proportions, while the perforated type did not light back under any condition. It is not likely, however, that the burner would be required to operate with very low gas flows. The multi-port burner requires only about one-third of the tunnel volume of the single-port type and thus can be made more compact, which may be an advantage for certain applications. With high flow rates of lean mixtures, it appeared to give more complete combustion than the single-port type. No assessment of the pressure drop across the perforated back-plate was made, but there is little doubt that the burner would have a considerably lower pressure efficiency than the single-port type. With the same thermal input and using the same exit-nozzle diameter, both burners should give a similar heating performance.

The results obtained so far definitely indicate that, the shorter is the tunnel, the less likely is the burner to be objectionably resonant. The optimum tunnel length for a practical burner must also take into account its heating efficiency, and further work is required in order to determine the best compromise. It would also appear that, the thicker is the perforated back-plate, the more silent will be the burner. The reason for this seems to be connected with the phasing of the upstream feedback, and experiments are being designed to elucidate this effect. The whole subject of upstream feedback and the nature of standing waves in the manifold and mixture tube is at present under investigation, together with the possibility of using some form of acoustical damper in order to neutralize this effect.

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A High-Temperature, Vacuum, Axial Fatigue-Testing Machine

By R. I. Stephens and G. M. Sinclair

From *ASTM Bulletin*, U.S.A.,
No. 249, October 1960,
pp. 44–47, 11 illustrations.

To determine the mechanical and physical properties of the refractory metals under non-oxidizing conditions, tests can be performed in an inert atmosphere or in a vacuum. Many high-temperature tests have been made with currently developed refractory specimens and parts, but most strength tests have dealt primarily with creep-rupture phenomena, and the determination of fatigue properties lags drastically behind the determination of other properties. High-temperature fatigue data on refractory metals is at a minimum, because commercial fatigue-testing equipment capable of isolating test specimens from oxidizing atmospheres is not available and special fatigue equipment has only recently started to be developed.

This paper describes versatile equipment designed to test thin-walled refractory-metal specimens in a vacuum at different frequencies and temperatures up to 2500°F under completely reversed stress, and also under an alternating stress superimposed on an either tensile or compressive mean stress. Consequently, data can be obtained at elevated-temperature conditions ranging from predominantly creep (low alternating-stress amplitude and high mean stress) to that of predominantly fatigue (high alternating-stress amplitude and zero mean stress). The heating element limits the temperature to 2100°F, but, since a tungsten heating coil is used, the maximum operating temperature can be increased with modifications in the coil support.

The maximum working load for the machine is ±2000 lb, permitting specimens with a nominal cross-sectional area of 0·02 sq in. to be subjected to alternating stresses up to ±100,000 psi. The machine is of the constant-displacement type, with the motion, or load, applied to the specimen through a horizontal level arm and an adjustable connecting rod and eccentric, driven by a 1750-rpm, constant-speed motor through a pulley arrangement to allow the load frequency to be varied. A turnbuckle on the connecting rod can be adjusted to compensate for thermal expansion in the specimen and grips. It is also used in conjunction with the adjustable eccentric to establish the maximum, minimum, and mean stress levels. The load is transmitted to the specimen through a vertical flex-bar and a calibrated ring dynamometer, which measures the applied load and consists of four active electrical resistance strain gauges fastened to a thick-walled ring.

The evacuated test-chamber is completely visible through a pyrex bell-jar seated on an O-ring seal, and axial load is transmitted into the chamber through a copper-alloy bellows. The stress σ in the specimen is easily calculated from $\sigma = P/A$, where P is the axial load measured on the ring dynamometer and A is the cross-sectional area of the specimen. Since specimens with relatively large outside diameters are used and high temperatures are present, adequate alignment is not difficult to obtain. Also, because the axial displacement of the bellows is quite small, even for highly stressed specimens, the possibility of the bellows failing in fatigue is very slight.

Notch Sensitivity in Steel

By E. Agerman

From *ASEA Research*, Sweden,
No. 4, 1960,
pp. 5–46, 74 illustrations.

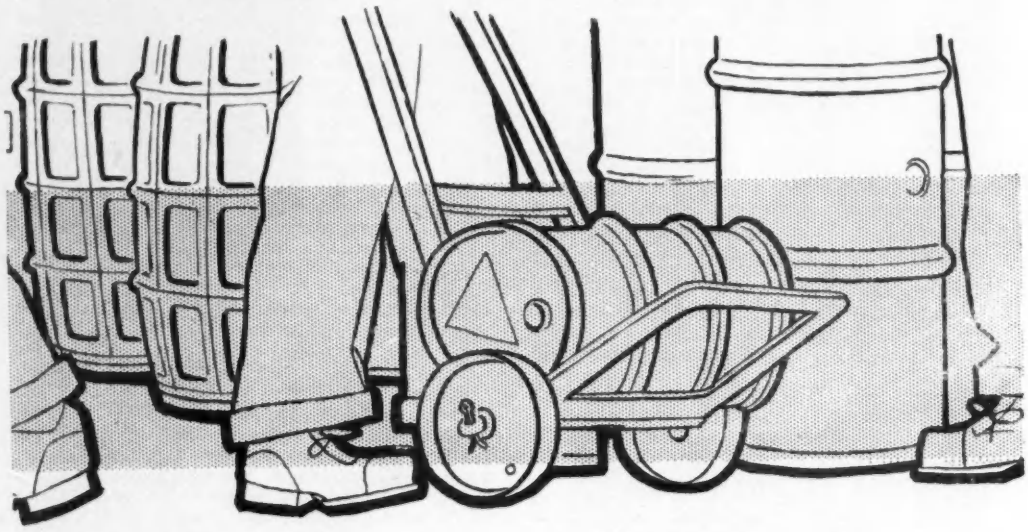
The fatigue strength of a machine part depends on a number of factors. Among these may be mentioned the type of stress (load spectrum), the desired life (number of load variations to fracture), the size and shape of the section under stress, the profile depth, the surface finish, and the quality of the material used for the part and the treatment to which it has been subjected. The influence of these factors cannot be calculated, but must be determined on the basis of empirical results. Attempts have been made to apply such results to formulate rules which will enable the influence of the different factors to be taken into consideration, interest being mainly concentrated on the dependence of fatigue strength on stress concentrations (notch effect).

This paper gives an account of an attempt made to compare various formulae for calculating the notch effect resulting from stress concentrations in the form of notches, fillets, and holes. In order to make this comparison impartial, it has been performed statistically, and since the data forming the basis of the theories and the investigation are empirical, the result naturally cannot be exact. Testing machines yield certain errors, and this must be considered. The accuracy of each of the theories is given in the form of a mean value and a dispersion. When evaluating the theories, preference is given to that having the smallest dispersion.

The paper shows that the best theory has been formulated by Neuber. With certain modifications suggested by Kuhn and Hardrath, and by others, this theory yields such good accuracy that the uncertainty expressed as a best estimate of the dispersion of a calculated value of the notch factor will be about 6% for normal carbon steels and about 9% for hardened steels. On the basis of this result, a method of calculation, developed with statistical reasoning, is described. Provided that both the load and the strength of a part can each be expressed with its mean value and its dispersion, it is possible to select the most economical safety factor (ratio between the strength and the load). A low safety factor results in, for example, small dimensions at a low cost, but a high risk of fracture. When making such calculations, it is assumed that the dispersion in the fatigue strength, the accuracy when determining the notch factor, the load spectrum of the machine part being designed, etc., are known.

The need for all the investigations to be performed with sufficient care became clearly apparent during their evaluation. Thus, for example, the Wöhler curves on which the empirical data are based must originate from a sufficiently large number of test specimens. A significant difference was established between results from, on the one hand, a test series having less than five specimens per Wöhler curve and, on the other hand, from test series having more than twenty specimens per Wöhler curve.

Tread and Trundle - Wear and Tear



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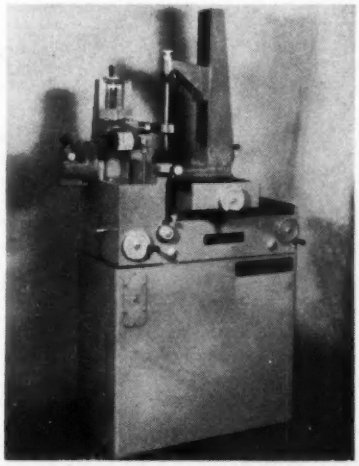
New Materials, Processes, and Equipment

Combined Involute and Helix Measuring Machines

The latest additions to the range of gear-measuring machines manufactured by the David Brown Tool Division, at Park Works, Huddersfield, are their No. 18 Series combined involute and helix measuring machines, which are designed to accommodate spur and helical gears having base-circle diameters of from $\frac{7}{8}$ to 18 in. When the centre locating column is in position, these machines will admit gears up to 12 in. in diameter, with 18 in. between centres. Gears with a base-circle diameter of up to 18 in. can be accepted when the centre column is removed.



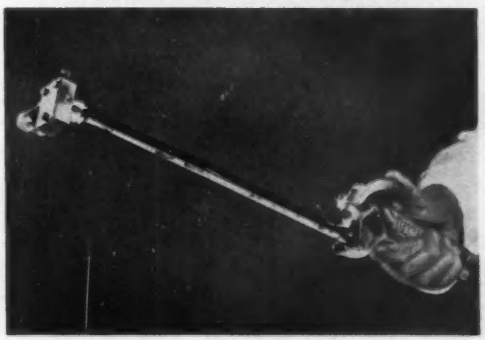
The No. 18 Series comprises two main models. Of these, the standard machine (No. 18) is equipped with the David Brown mechanical recorder, which has a magnification ratio of 500 : 1, the ratio of graph length to slide movement being capable of variation between 1 : 1 and 3 : 1. The second model (No. 18T) is a special version which incorporates the "Talymin" side-acting gauge-head, with an electronic rectilinear recorder and amplifier, giving magnifications of from ×500 to ×5000. A gearbox in the recorder permits the ratio of the chart length to that of the appropriate slide movement to be 1 : 1, 2 : 1, or 4 : 1. In both models, variations of the order of 0·0001 in. can be accurately recorded.

For involute measuring, these new testers use the principle of individual base-circle discs for each size of gear under test, so as to ensure positive setting and a high degree of accuracy. The actual procedure for involute testing is simple in operation: With the gauging point of the recorder stylus located exactly above the face of the straight-edge, the base disc, mounted coaxially with the gear under test, is brought into contact with the straight-edge. Rolling of the base disc along the straight-edge causes the gauging point in contact with the appropriate gear-tooth flank to describe the designed involute curve. If the flank is a true involute, a straight-line graph will be recorded, any deviation from the true involute being recorded by the movement of the pen across the graph paper. By the same means, modified tooth forms can be recorded for comparison with the designed profile. Scales are provided on the machine, so that positions where departures from the involute form occur can be accurately located.

The procedure for helix testing is also simple to apply. By combining vertical movement of the stylus with the corresponding rotational movement of the gear, the gauging point describes the correct helix. The vertical slide carrying the recorder also houses the helix disc, rotation of which allows the centre-line of the slot machined in its face to be inclined at the base helix angle of the gear. The straight-edge, mounted on a sensitive slide, is coupled to the helix by means of a block which is free to slide in the helix disc slot. An illuminated direct-reading microscope is provided for setting the base helix angle. The base disc is brought into contact with the straight-edge and the gauging point of the stylus into contact with the tooth flank at one end of the gear face. The movement of the vertical slide causes the stylus to traverse axially across the gear face, whilst the helix disc moves the straight-edge and causes the gear, mounted co-axially with the base disc, to rotate by the correct amount. Any deviation from the correct helix, measured in the transverse plane of the gear, is thus recorded.

Hand Spray-Gun for Cleaning and Lubricating Dies

Designed specifically for use with pressure diecasting machines, a new hand spray-gun introduced by the Foundry & Metallurgical Equipment Co. Ltd., of Weybridge, Surrey, provides an air jet for cleaning the dies and an oil-mist spray for efficient lubrication. The air jet and oil spray are independently operated and are applied at right-angles to the die faces to permit penetration into deep cavities. Positioning of the gun is facilitated by swivel-joint connections for the flexible air and oil hoses. The gun is fitted with stainless-steel valves and has a single lever-action control that gives immediate



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response. The density of the spray can be adjusted and then locked.

The gun can be supplied with a single-facing head, as shown in the illustration, for spraying one die at a time, or with a double-facing head for spraying two dies simultaneously. Each head carries a phosphor-bronze scraper blade for cleaning flash from the joint of the dies, and a suspension hook for hanging up the gun between operations. The gun, which is available with tube lengths of 8, 12, and 18 in., is supplied complete with a 1-gal oil container, with filter and hinged lid, and two 6-ft armoured hoses.

Oiler for the Controlled Lubrication of Strip Materials

Though basically intended to cater for the need for accurate cleaning and lubrication of strip materials before feeding into power presses, a new oiler announced by Clark's Press Equipment Ltd., of West Drayton, Middlesex, can also be used to advantage for the application of degreasers or thinners prior to follow-on operations on strip.

Providing controlled lubrication, the new oiler, which is designed for easy attachment to an automatic press feed or press bed, comprises a side-opening box containing rotating felt rollers. Individual needle valves control the amount of lubricant fed from a storage bottle to the core of the rollers, while rubber squeegees at the point of entry clean the material as it passes. This method of feeding liquid to the inside of the roller ensures that there is no open reservoir or excess amount of lubricant. As a result, the lubricator and its vicinity are kept clean and there is no wastage. The storage bottle is refilled by opening the top half of the box to an inverted position, enabling the bottle to be removed or replaced without spilling its contents.

High-Speed Loom for Making Lace

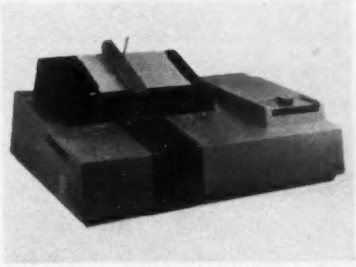
After several years work at Nottingham University on the development of lace looms, Professor J. A. Pope and Dr. H. McCallion have invented a new loom for making lace at high speed and with reduced labour requirements. As a result, it is considered that it could help the industry to market genuine lace under more favourable conditions than have hitherto been possible. Results obtained with a small prototype indicate that a speed five times higher than that of present machines is feasible. Possible subsidiary advantages are the production of first-quality lace over the full length of the loom and the complete elimination of graphite lubricant.

The new loom, which is covered by patent applications in the U.K. and abroad, and which is available for manufacture under licence from the National Research Development Corporation, embodies a radically new design approach, aimed at reducing the high inertia of conventional looms. The loom utilizes stationary bobbins and guides the warp threads around the bobbin threads by means of rotating drums carrying needles which pick each thread from the warp, pull it clear of the bobbin, and release it at the appropriate time. The warp threads are controlled in position by a steel-bar jacquard, as is usual with conventional machines.

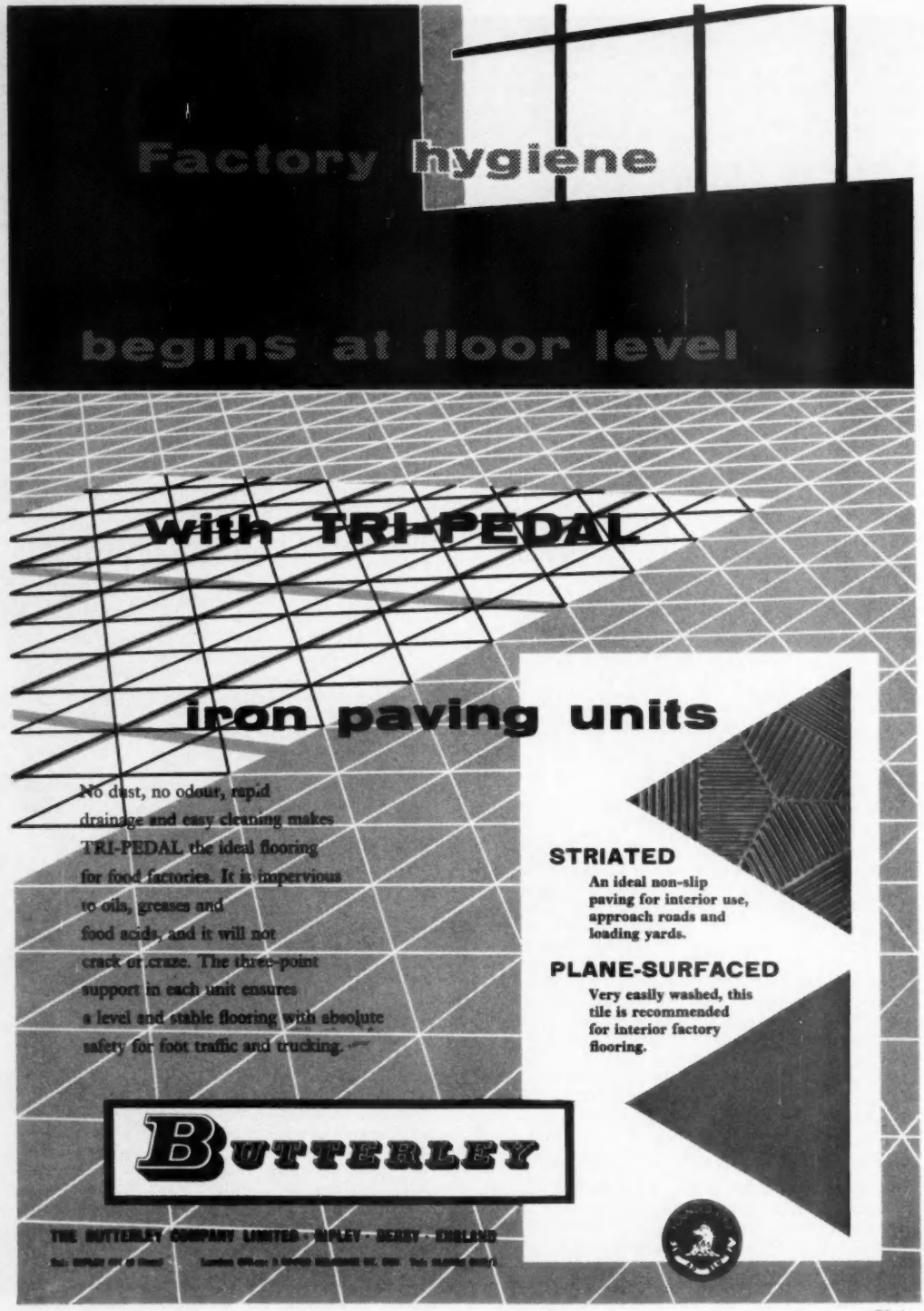
As a necessary corollary to the high-speed lace loom, Dr. McCallion has also designed a high-speed jacquard, which seeks to overcome the speed limitations inherent in conventional punched-card jacquards, though it may also be applicable to other textile machinery requiring a pattern control system.

Infrared Spectrophotometer for Routine Analysis

The "Unicam" SP.200 infrared spectrophotometer, announced by Unicam Instruments Ltd., of Cambridge, is essentially designed for routine analysis, but incorporates several features which greatly increase its scope—a particularly important factor in cases where users do not have access to a large instrument. Spectra are presented on charts of foolscap size, ruled with scales linear in wavenumber and transmittance. The recorder is of the flat-bed type, and the chart carriage is drawn past a ball-point pen, the pressure of which is sufficient to produce carbon copies, where required. The scan, which covers the range 650 to 5000 cm^{-1}, is completed in ten minutes, only a few seconds being needed for resetting. Control, under normal conditions, is exercised by one small lever, and the scan can be started and stopped at any point.



The photometer is of the double-beam null balancing type, with a Nernst filament as the source. The radiation enters the monochromator at a frequency of 10 cps, and slits are programmed to pass a level of energy which is constant over the range. The level of the programme can be varied in cases where, for example, there is strong absorption in the reference beam, and the energy of the system restored to the normal level. A 60-deg. rock-salt prism is used as the dispersing element, and the radiation is finally focused onto the Golay detector, whose advantages include a large receiving area and a uniform response throughout the wavenumber range. The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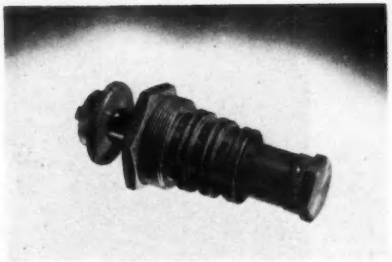
TP. 21

associated electronics are mounted in three small chassis, and a monitoring system is provided.

The instrument is equipped with the standard type of slide mounts and will accept the majority of cells in use with infrared apparatus, a very wide range being available. Special accessories enable expansion of any chosen portion of the transmittance scale to be achieved easily. Fixed-frequency scanning can also be undertaken.

Adjustable Cartridge-Type Flow-Regulator

A new externally adjustable, cartridge-type, low-capacity flow regulator, designed to maintain a constant regulated flow, irrespective of variations in pressure, is announced by the Fluid Regulator Corporation, of Painesville, Ohio. Whenever the inlet flow exceeds the valve setting, this new valve, which is constructed of stainless steel and anodized aluminium and weighs only 9 oz, opens to by-pass flow to the reservoir and maintains constant flow to the circuit.



Intended for use in hydraulic circuits requiring a low flow, the valve has an adjustable regulated flow from 0 to 0·4 gpm approximately, and an adjustable total flow-control rate of 5% within an operating pressure range of 600 to 2000 psi. In addition, it has a low pressure drop of about 50 psi at 0·1 gpm.

Low-Cost Nitrogen/Hydrogen Atmospheres from Blast-Furnace Gas

"Hy-Nitrogen", sometimes termed HNX, consisting of nitrogen with from 1 to 7% hydrogen, is finding increasing use in the heat treatment of steel strip and sheet. The gas provides a truly inert atmosphere for bright annealing and does not form soot on cooling, as it does not contain carbon monoxide, while the hydrogen is present in sufficient quantities to combine with any oxygen leaking into the furnace and also to prevent water vapour from causing bluing.

The demand for this type of atmosphere has led the Gas Atmospheres Division of the Incandescent Heat Company Ltd., of Smethwick, Birmingham, to develop a new process for producing nitrogen/hydrogen mixtures from blast-furnace gas at very low operating costs, the basic utilities costing less than one shilling per 1000 scf of prepared atmosphere.

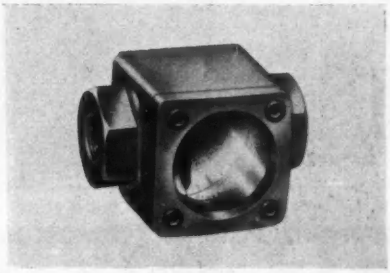
In the new process, blast-furnace gas (containing about 30% carbon monoxide with a small amount of hydrogen and the balance nitrogen and carbon dioxide) is first partially burned through a specially designed burner firing into a well-insulated refractory-lined chamber, from which the gases pass through a heat exchanger and cooler to reduce the temperature to within a few degrees of ambient. The carbon dioxide is then removed through a highly efficient absorber of special design, using monoethanolamine solution. The composition of the gas leaving this unit is approximately 93 to 99% nitrogen and 7 to 1% carbon monoxide. Steam is introduced at this stage, and the gases are preheated prior to entering the shift reactor, where the carbon monoxide is converted to carbon dioxide and an equivalent volume of hydrogen is produced. After removal of the carbon dioxide through a second monoethanolamine absorber, the wet hydrogen/nitrogen mixture leaves the plant. Final drying can be effected to any desired level by cooling the gas through a refrigerator unit, followed by passing it through a desiccant-type dryer.

The whole plant is designed for continuous operation with a minimum of attention or shut-down time, and all coolers are suitable for maintenance on the water side while the plant is running. Basic designs now available cover 10,000, 25,000, 50,000, and 100,000 scfh units, but schemes can be prepared for any size of installation to meet customers' requirements.

Flow Indicators for Opaque Liquids

Designed to overcome the problem of observing the flow of opaque liquids through pipe-lines, the new range of "Magnetel" flow indicators introduced by Sir W. H. Bailey & Co. Ltd., of Patricroft, Manchester, is of simple and efficient construction and can be used with liquids of almost any viscosity. The internal parts of the unit, which is equally suitable for indicating flow either horizontally or vertically upwards, are readily accessible for cleaning while the body is still in the line.

The indicator incorporates a chamber and, as the fluid travels through this chamber, it moves a hinged metal flap fitted with a magnet which serves to operate a pointer against a scale. As there are no springs or other moving parts, the risk of mechanical breakdown or jamming is eliminated and, as the pointer and scale are in a separate chamber, the fluid cannot obscure the viewing window. A particular feature is that the indicator can easily be adapted for extremely low flow rates, while its fine sensitivity ensures that the smallest change in relative flow is shown on the scale. It will also accept a wide range of capacities when full flow is shown on the scale.



In cases where the liquid may contain ferrous particles which might adhere to the magnet, a special screened model is available, in which the magnet is fully enclosed in an intermediate chamber. In addition, a special switched version can be supplied, in which a switch is automatically operated to give a reinforcing audible indication of an emergency when flow stops completely or falls below a certain rate.

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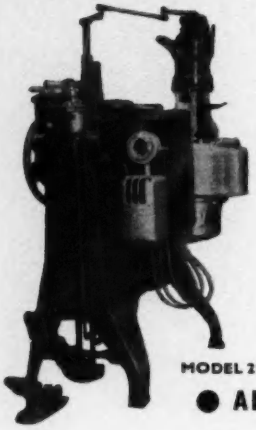
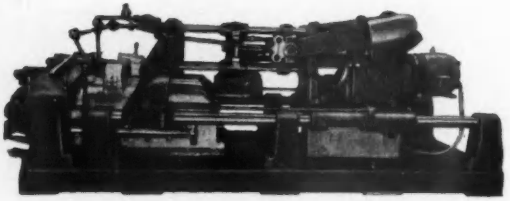
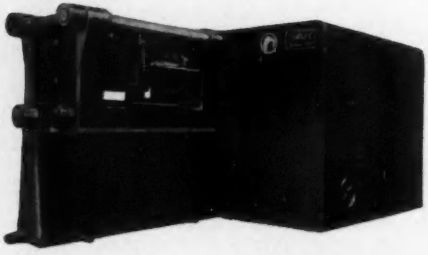


MODEL 215E



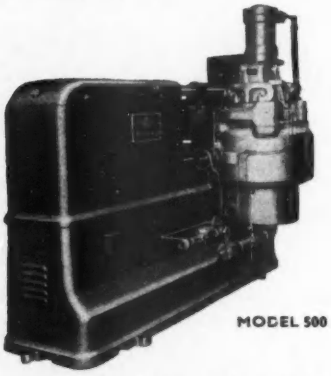
MODEL 4

● ABSOLUTE ACCURACY



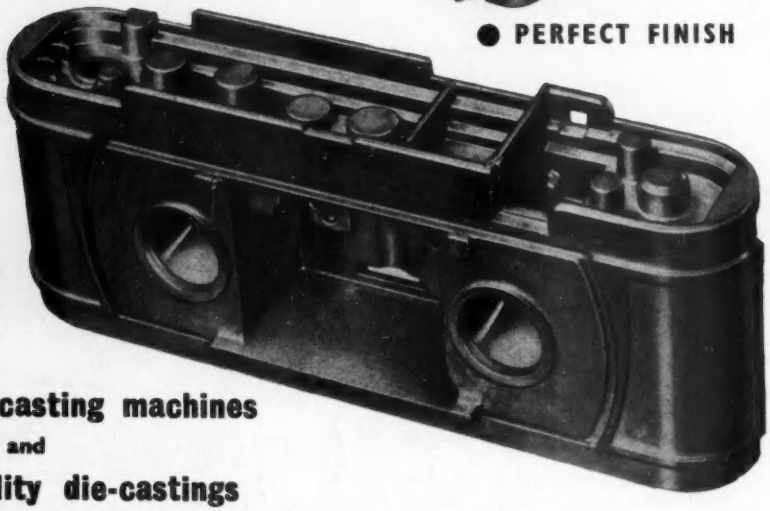
MODEL 450

● STRENGTH



MODEL 500

● PERFECT FINISH



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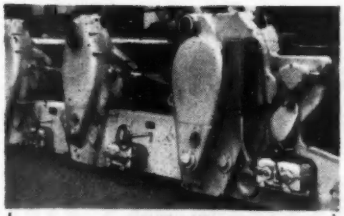
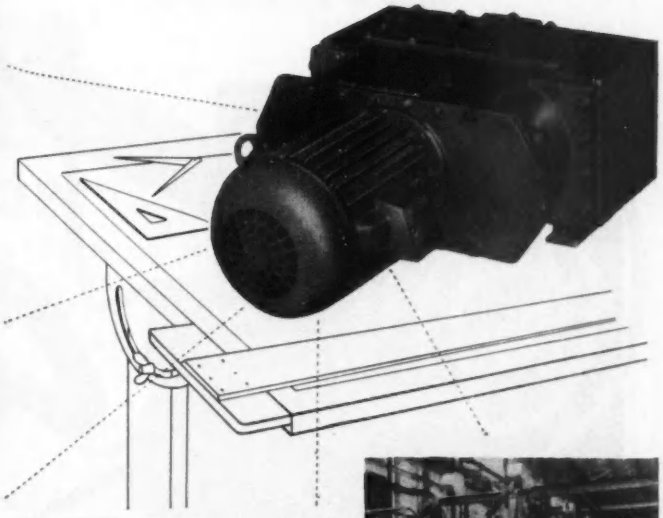
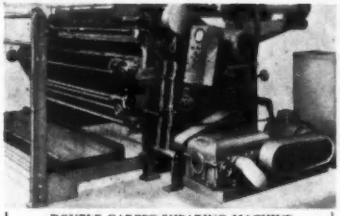


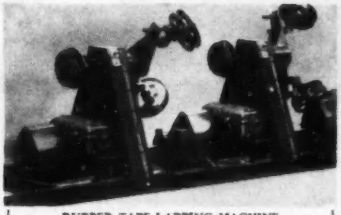
BAKERY OVEN
Courtesy T. & T. Vicars Ltd.



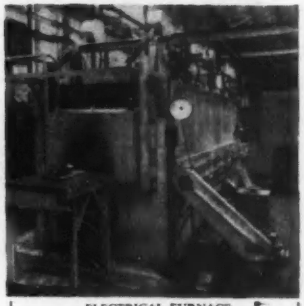


DOUBLE CARPET SHEARING MACHINE
Courtesy William Whitely & Sons Ltd.

FILTER
Courtesy Davey Paxman & Co. Ltd.



RUBBER TAPE LAPPING MACHINE
Courtesy B. & F. Carter & Co. Ltd.



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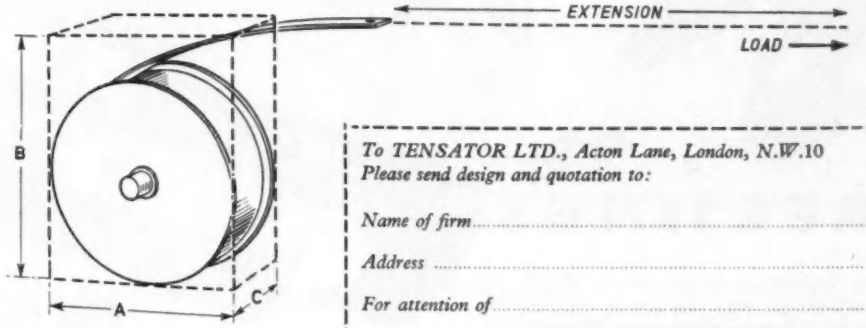

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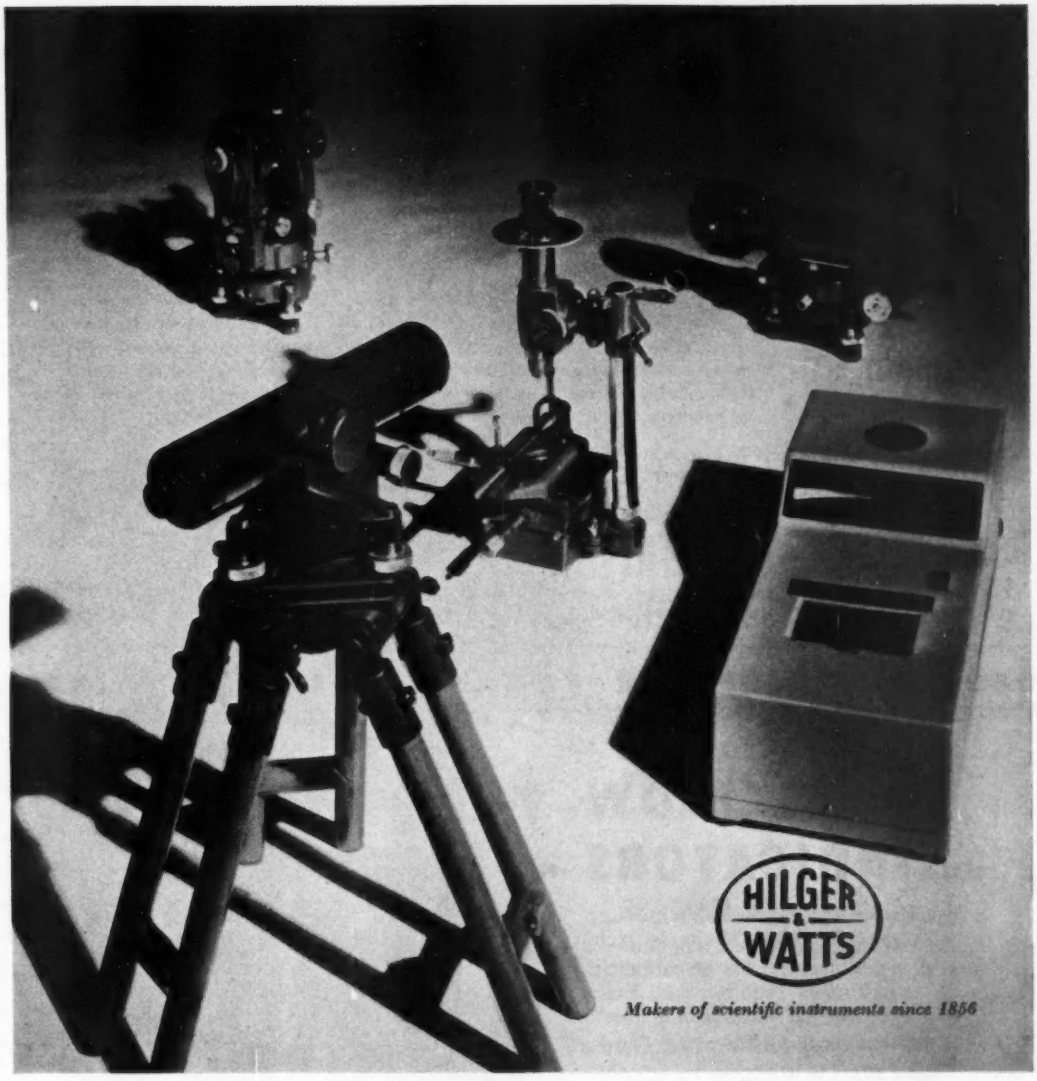

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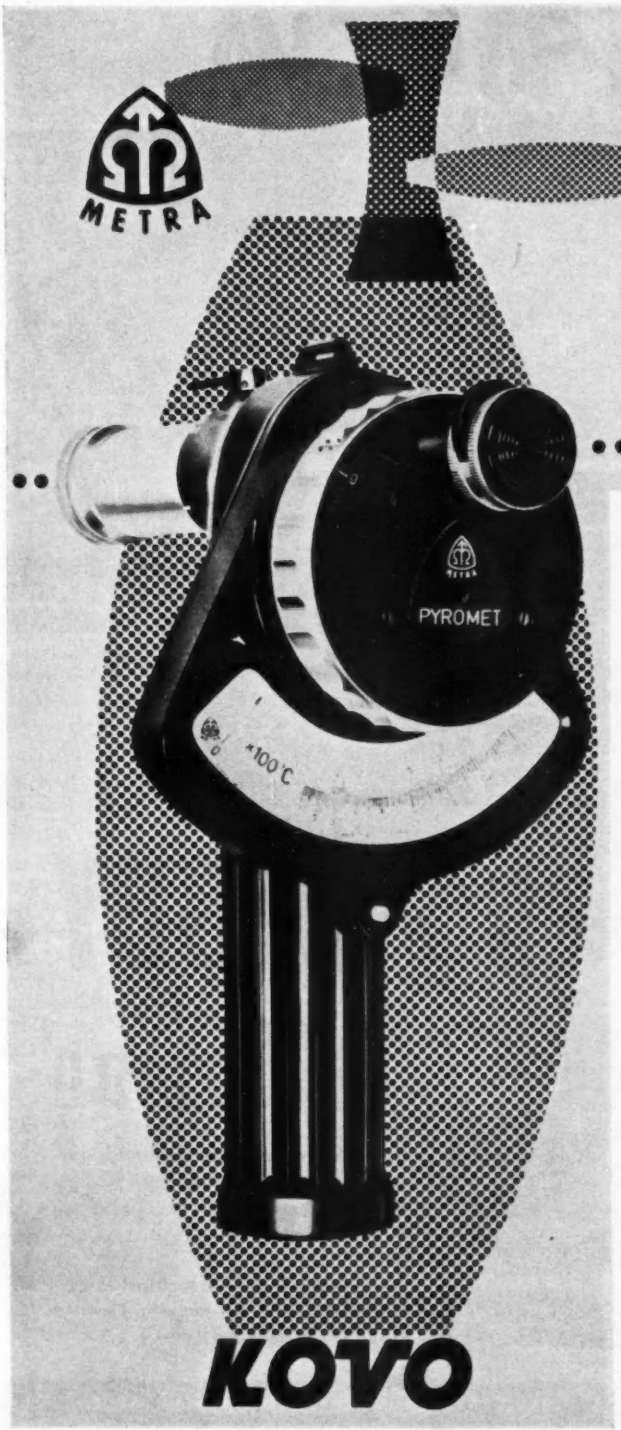

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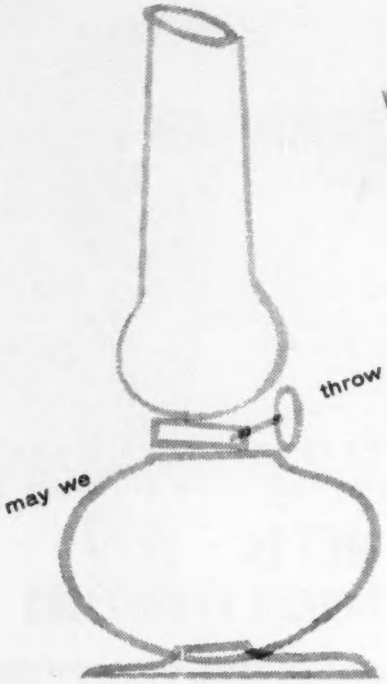

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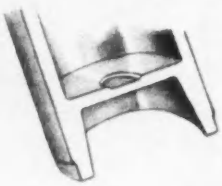
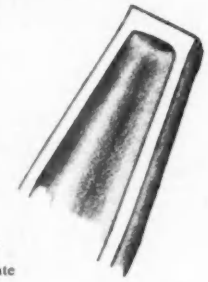


throw some light on the subject of . . . hollow extrusions



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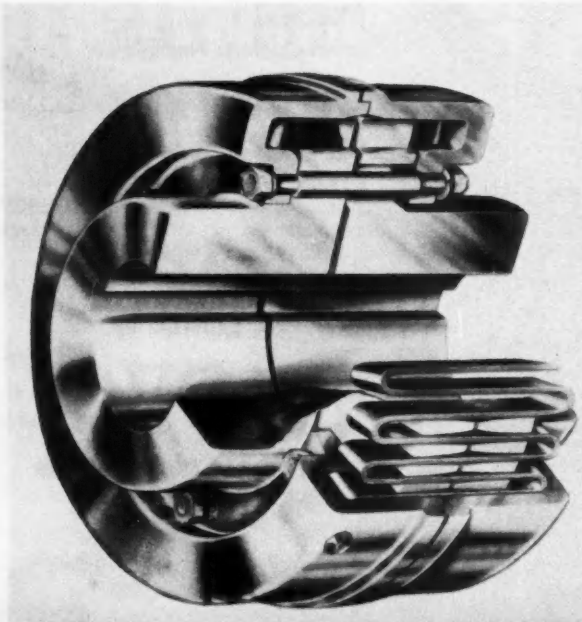

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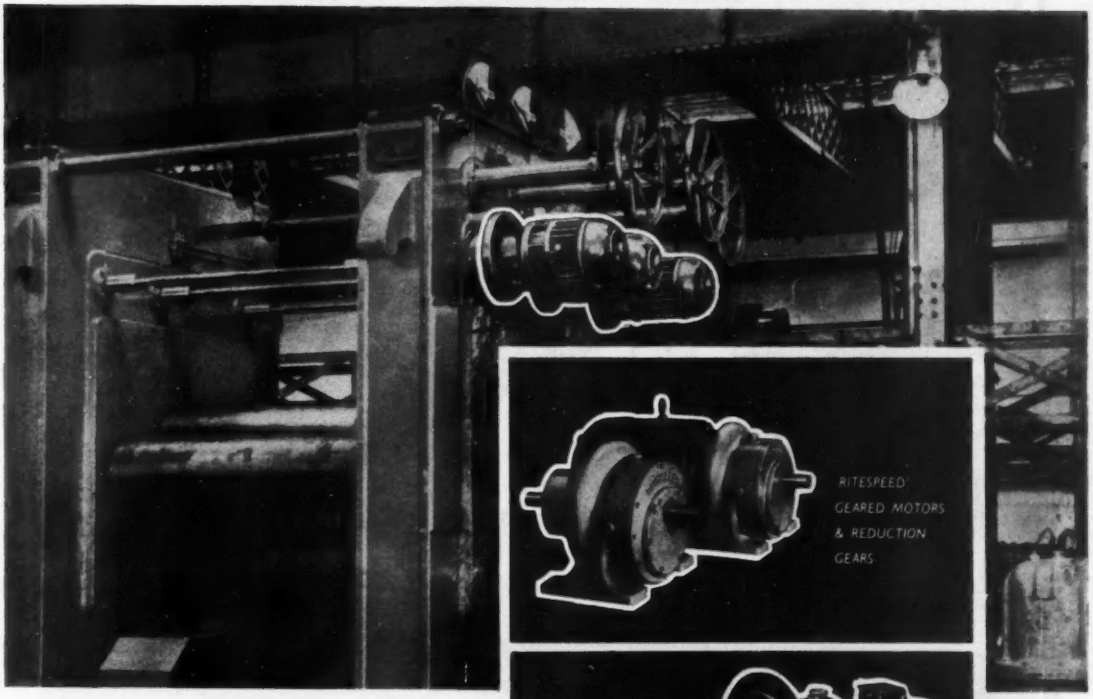

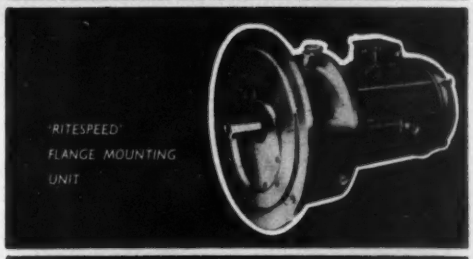

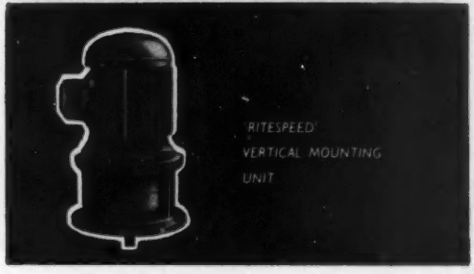

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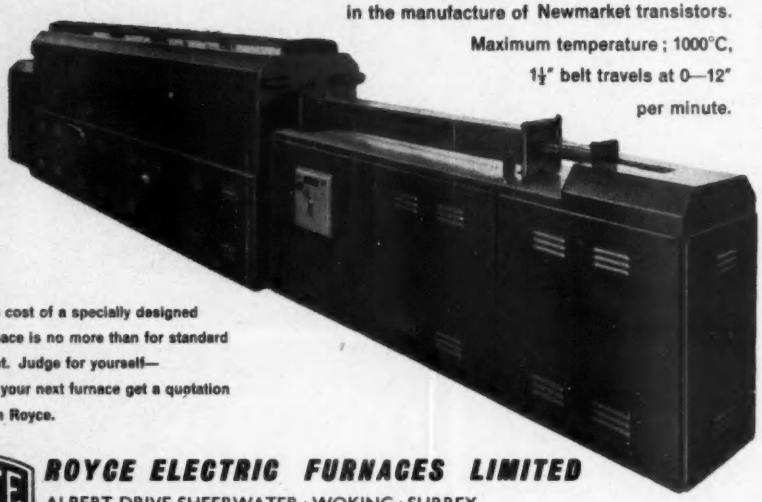

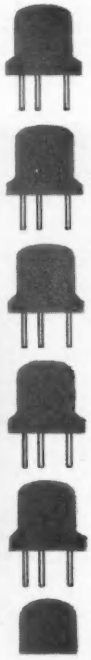

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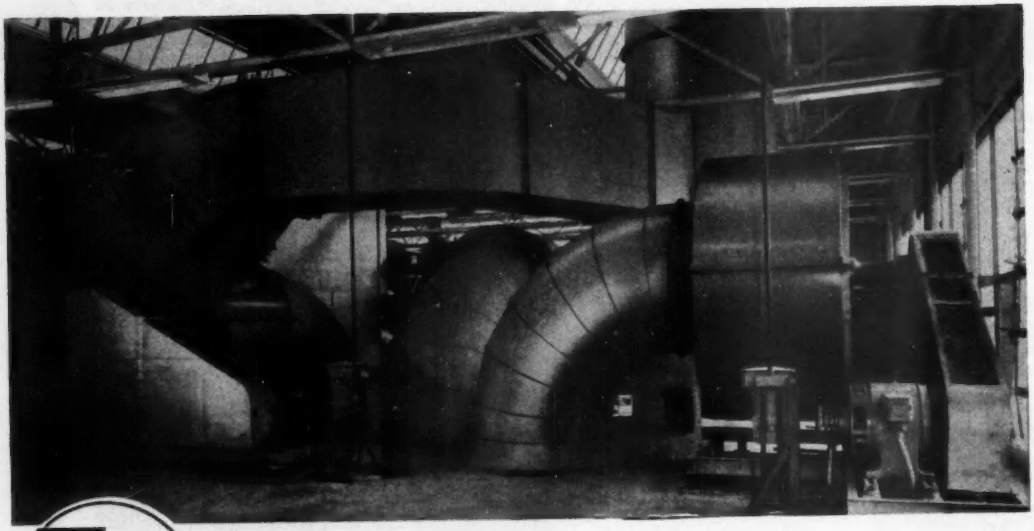

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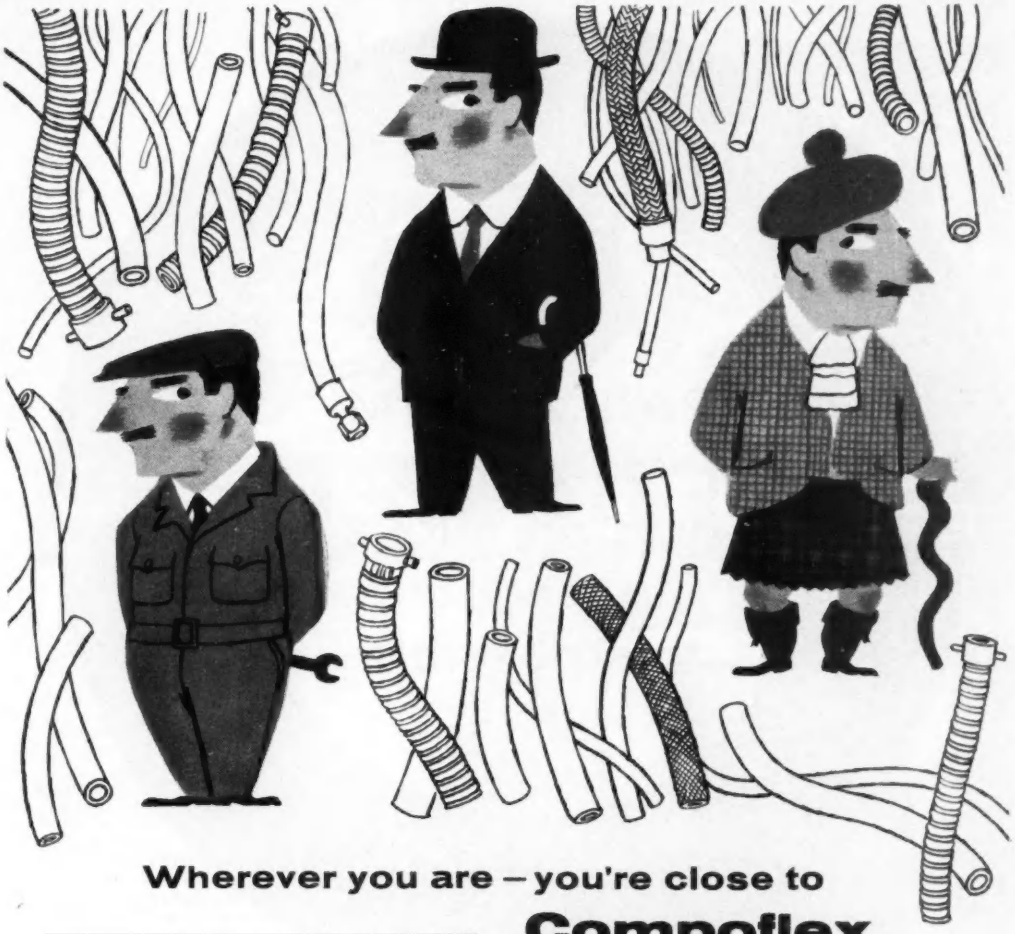

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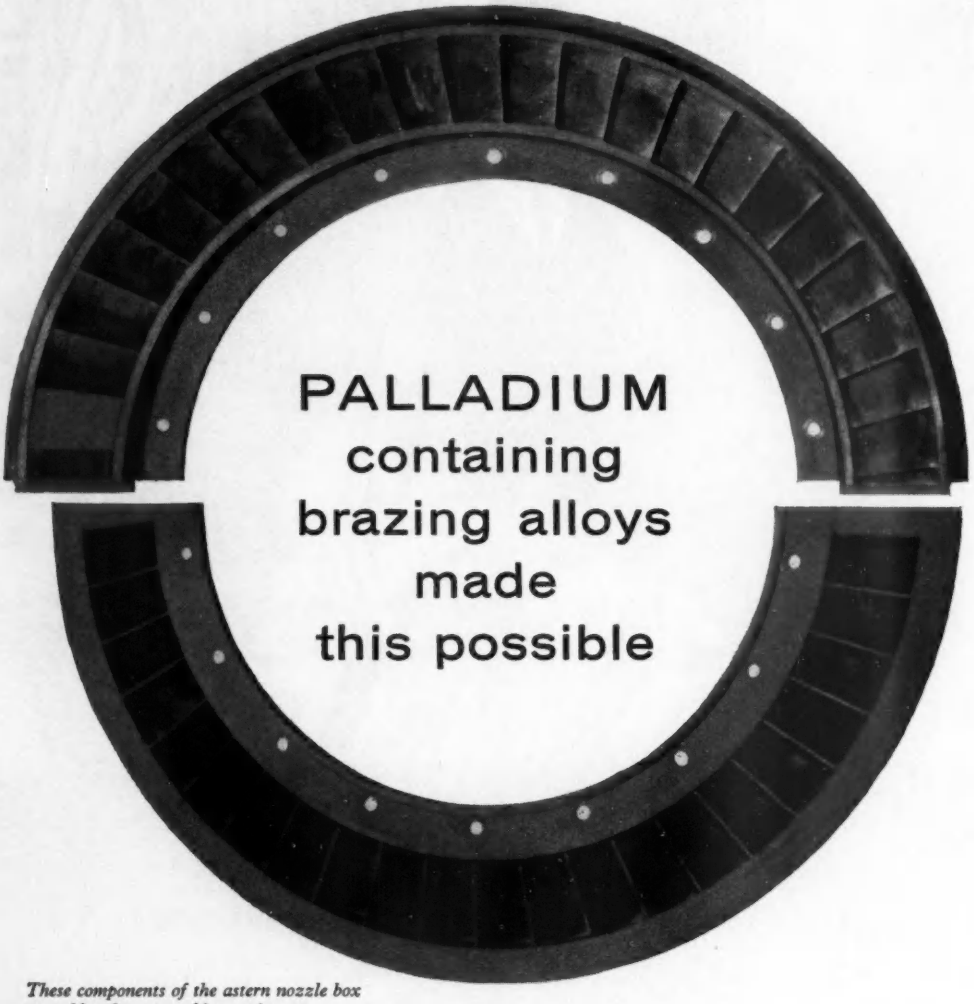

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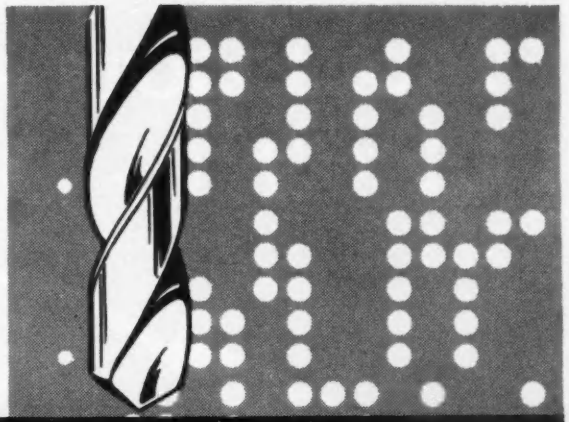

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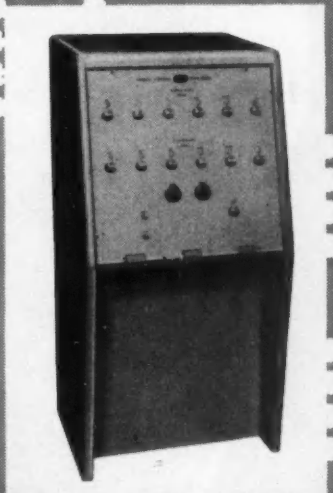

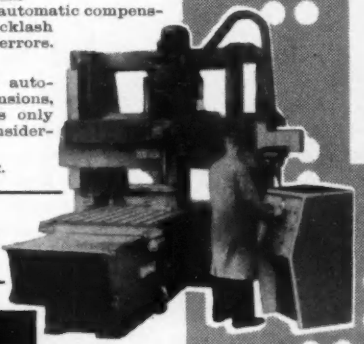

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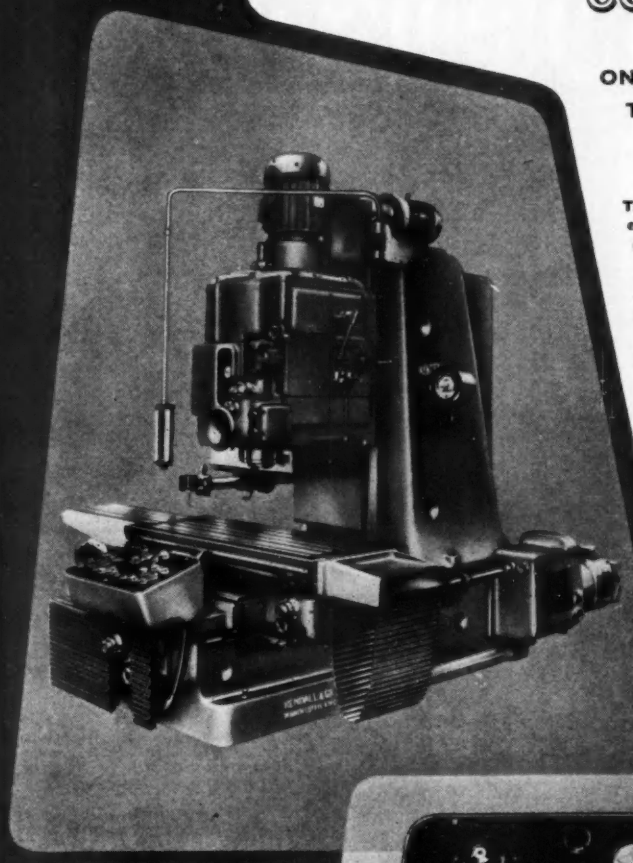

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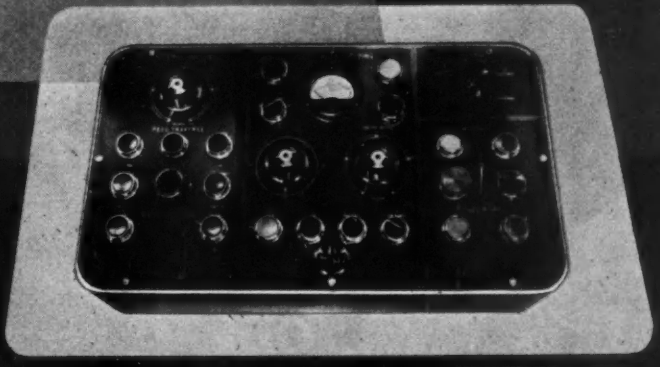

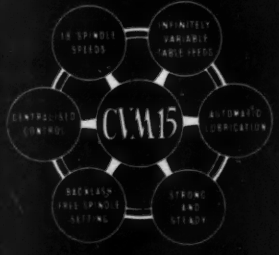

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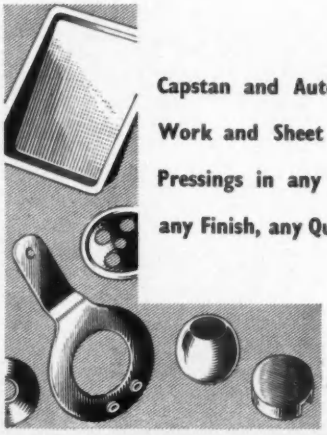

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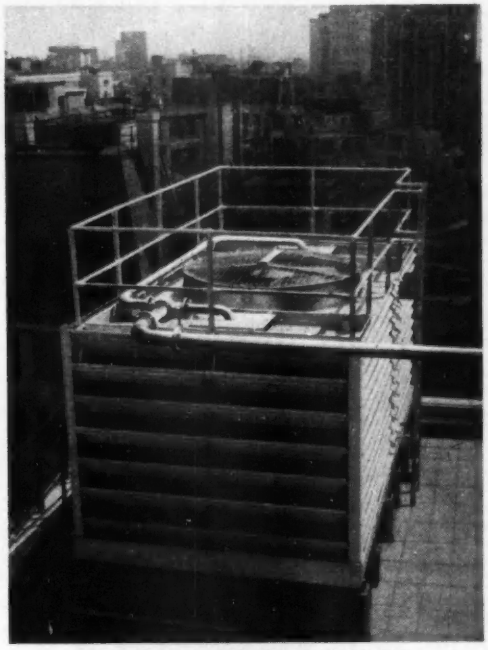

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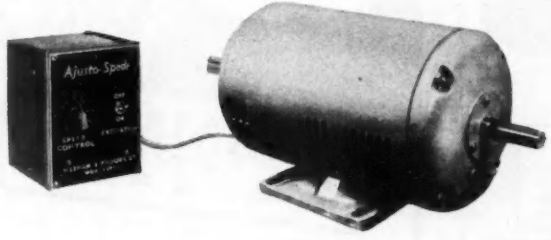

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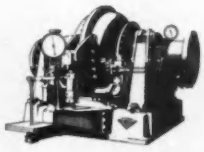

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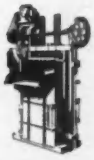

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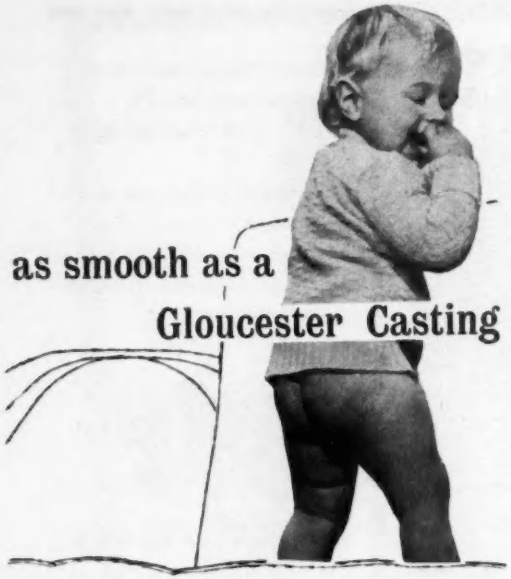

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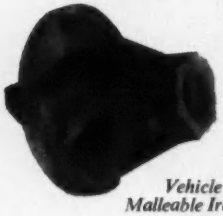

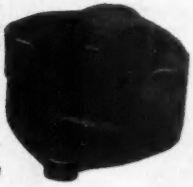

Right:
Spring mounting bracket in Malleable Iron Weight 8½ lbs.

Left:
Vehicle pinion housing in Malleable Iron. Weight 28 lbs.

A typical Gloucester Malleable specification.

Gloucester Blackheart Malleable		*Gloucester Lamellar Pearlitic Malleable*	
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Yield Point	12 tons	Yield Point	24 tons
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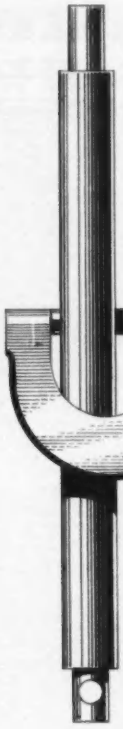

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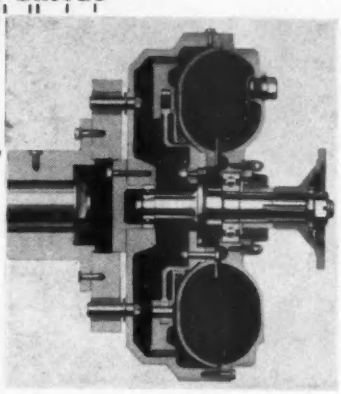

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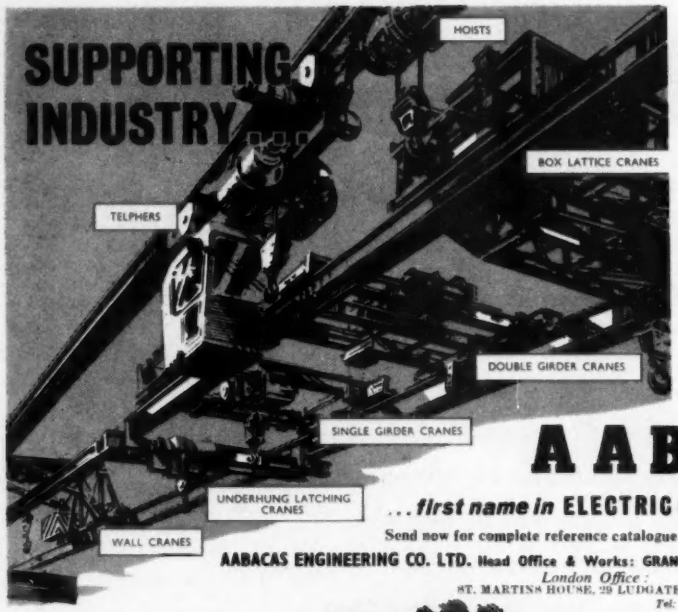

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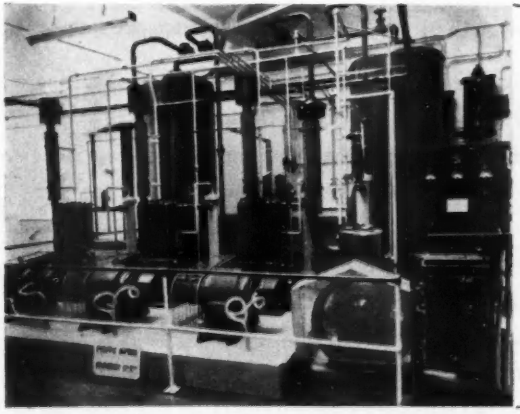

Three of the latest type "BROOMWADE" Type C660 Carbon Ring Oil Free Air Compressors installed by Messrs. Phipps Northampton Brewery Company Limited, by whose courtesy this photograph is reproduced.
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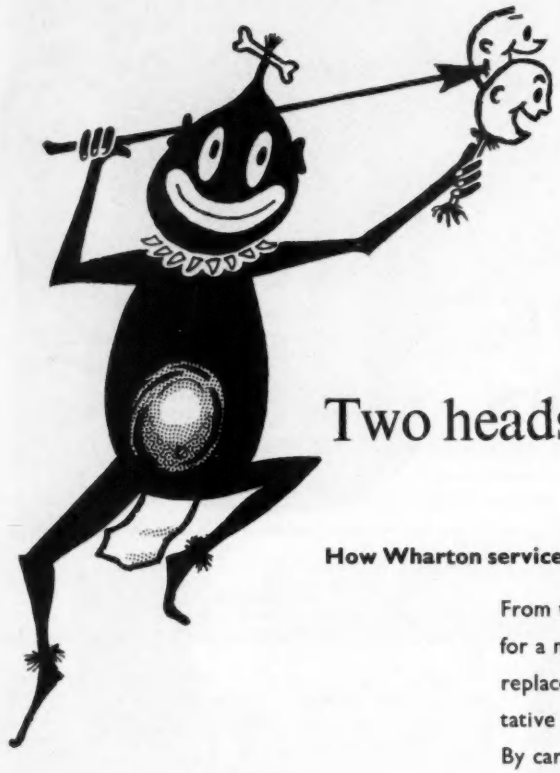

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Magisol:
special solvent blend removes grease and oil from metal surfaces.

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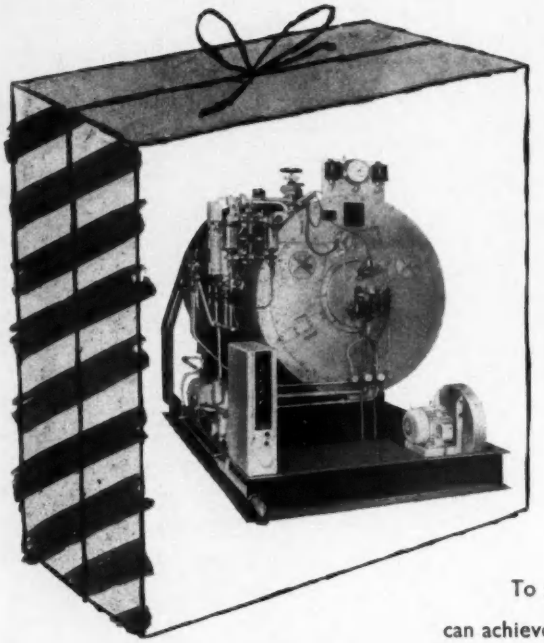

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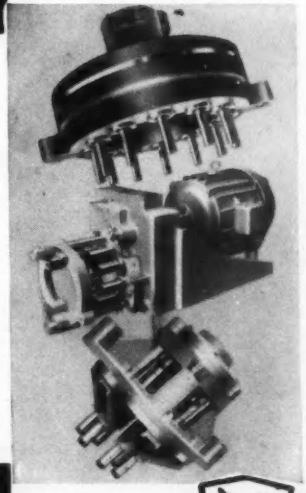

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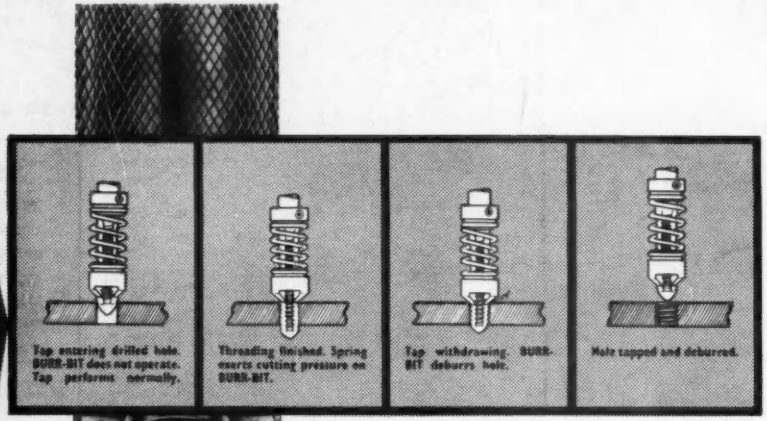
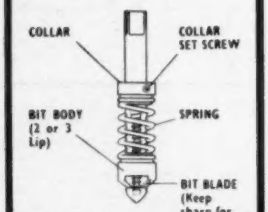

Tap entering drilled hole. BURR-BIT does not operate. Tap performs normally.
Threading finished. Spring exerts cutting pressure on BURR-BIT.
Tap withdrawing. BURR-BIT deburrs hole.
Nuts tapped and deburred.



Fitted to the tap in seconds! Adjustable to suit thread depth.

For use with standard 2, 3, or 4 flute taps, on tapping machines, in tapping heads, on single and multi-spindle automatics, capstan and turret lathes.

For most materials — steel, cast iron, aluminium, brass, copper, plastics.

***SAVE** time, floorspace, manpower; **BURR-BIT** eliminates an extra machine, functions only as the tap is being withdrawn. No extra power is used.*

***CLEAN HOLES** — **BURR-BIT** chamfers while the tap is withdrawing, burr is not pushed into the hole.*

***AIDS ASSEMBLY** — **BURR-BIT** leaves clean thread lead. With burr removed parts are easily mated.*

deburrs & chamfers as tap withdraws

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